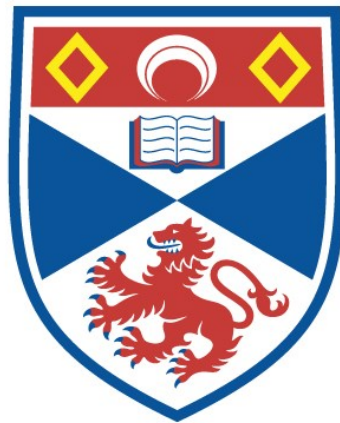


**EARLY DEVELOPMENT OF STRATEGIES FOR MAPPING  
SYMBOL-REFERENT RELATIONS : WHAT DO YOUNG  
CHILDREN UNDERSTAND ABOUT SCALE MODELS?**

**Tracy L. Solomon**

**A Thesis Submitted for the Degree of PhD  
at the  
University of St Andrews**



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SYMBOL-REFERENT RELATIONS:  
WHAT DO YOUNG CHILDREN UNDERSTAND ABOUT SCALE MODELS?**

by

**Tracy L. Solomon**

A thesis submitted in conformity with the requirements  
for the degree of Doctor of Philosophy  
School of Psychology  
University of St. Andrews

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## Abstract

The research reported here investigated the nature of young children's understanding of a novel symbol—a scale model. Children witnessed the hiding of a small toy in a scale model of a room and were then required to search for an analogous larger toy that had been surreptitiously hidden in the actual room. At issue was whether children succeed by attending to the target location (object strategy), to the spatial location of the target location (spatial strategy), or to both types of information. It has been suggested that at three years of age (the age at which children first succeed on the task) children succeed by recognizing the correspondence between analogous objects in the two spaces (Bence & Presson, 1997; Blades & Cooke, 1994; Perner, 1991; Lillard, 1993) but that an understanding of the model *as a whole* as a representation of the room necessitates also attending to the spatial relations between the objects (Perner, 1991; Lillard, 1993). In five Experiments, children participated in versions of the model task that varied in the type of information (object and/or spatial) available to solve the task. The results revealed that although, in general, children rely primarily on the identity of the individual objects to find the hidden toy, the spatial relations between the objects may also influence task success. Furthermore, there was strong evidence of individual differences in children's strategies which appeared to be linked to sex, with girls attending primarily to the identity of the objects and boys demonstrating a fledgling ability to approach the model spatially. Some children also appeared to label the target object but the labeling strategy could not account for girls' tendency to attend to the objects more than boys. It is suggested that characterizations of an abrupt shift between three and four years of age in the ability to interpret the model *as a whole* as a representation of the room may be misleading. There may be multiple developmental routes to the gradual acquisition of an explicit understanding of a scale model as a symbol for the space it is intended to represent.

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## **Chapter 1**

## Introduction

A hallmark of mature human cognition is the ability to understand symbols. In western civilization, symbols are ubiquitous in everyday life; calendars, clocks and watches denote the passage of time and are thus essential for planning activities, computer icons indicate the type of software accessible for manipulating information and in many countries, the well-known airplane silhouette appearing on road signage is essential for directing visitors to the local airport. As these examples demonstrate, the type of symbols one regularly encounters varies widely. Some symbols are highly iconic or perceptually similar to their referents such as photographs, real-life videos and the scale model replicas used by architects to depict future real-estate developments. The referents for other symbols are more abstract; as when a dove or laurel branch denotes peace or a skull and cross bones is used to indicate danger. Still other symbols derive their meaning, at least in part, through their combination with symbols belonging to the same symbol system such as letters and words, numbers, hieroglyphs, braille and the symbols used in computer programming languages. So numerous and ubiquitous are the symbols encountered in everyday life that mastering them can be considered essential for full participation in western culture (DeLoache, de Mendoza & Anderson, 1999; DeLoache & Smith, 1999).

The critical advantage of acquiring the ability to think about and reason in terms of symbols is that cognition becomes de-contextualized or freed from the here-and-now (DeLoache, 2000; Werner & Kaplan, 1963). As entities in and of themselves, independent of their referents, symbols permit thinking about that which is beyond current sensory input. Thus, for example, one can think about the location of Portugal relative to the Mediterranean and Atlantic oceans by inspecting a globe or world atlas and without ever visiting the country itself. And complex mathematical expressions, for

the few that understand them, can be solved by the ability to think in terms of the four or more dimensions they represent-- clearly well beyond what can be perceived directly. It is this capacity for abstract thinking afforded by symbols that make them essential tools for reasoning and problem-solving (Vygotsky, 1978). Given the prevalence of symbols in western culture and the implications of symbolization for cognition more generally, it is perhaps unsurprising that investigating the origins and early development of the ability to understand symbols is a topic of great interest to cognitive developmental researchers.

This dissertation is concerned with young children's ability to understand the relation between a particular symbol—a scale model—and its referent, the room the model stands for. As children are unlikely to have had experience with a scale model depicting a specific, unfamiliar environment, scale models afford the opportunity to investigate how children first come to understand symbol-referent relations as well as the factors that influence that understanding. The research reported in this thesis attempts to elucidate the nature of that understanding and its development during the pre-school years. This introductory chapter is organized as follows: First, to help place the work in context, the definition of a symbol adopted throughout the thesis is presented. This is followed by a description of the standard scale model task (see DeLoache, 1987b; Uttal, Schreiber & DeLoache, 1995; Marzolf, 1996) and the “Dual Orientation Hypothesis”, a theory of the cognitive processes thought to underlie success on the task (see e.g. DeLoache, 1987b; 1995). The next section contains a summary of the research investigating the factors that influence young children's understanding of scale models and the conclusions drawn from that work. An alternative interpretation of these findings and its implications for our understanding of early symbolization and representation more generally is then delineated and the chapter concludes with an

overview of the experiments carried out to address this possibility and their organization in the remaining chapters of the thesis.

### Definition of a Symbol

The definition of a symbol adopted in this thesis is any external representation that the user intends to stand for something other than itself. Symbols are cultural artifacts created for the express purpose of communication (Tomasello, 1999). They are physical entities or objects in the real world and are therefore *external* representations of their referents, distinct from *internal*, mental representations of the world such as cognitive maps (Liben, 1997; Mandler, 1983). Furthermore, what makes something a symbol is the communicator's intention that it is interpreted in terms of something other than itself (Tomasello, 1999; Sharon, 1999a; 1999b). Thus, even something that does not resemble its referent in any way can serve as a symbol; e.g. two hands held together at right angles can serve as the intersection of roads when giving directions. What is essential is that the user intends the gesture to be interpreted in terms of the environment it represents (and of course, that the receiver interprets it in this way). As Dalke puts it, "the representational relation [between symbol and referent] resides in the mind, not in the objects that are used as representations." (Dalke, 1998, page 67). Although grasping the relation that holds between a symbol and its referent is typically straightforward for a normally functioning adult, as the following summary of the literature on young children's understanding of scale models will reveal, this is not the case for very young children.

### The Scale Model Task

Much of the work on young children's understanding of scale models has been carried out by Judy DeLoache and her colleagues (see DeLoache, 1989b; 1990b; 1995; DeLoache, Miller & Pierrotsakos, 1998). On the standard task, children are introduced

to a room and a scale model replica of the room containing the same (except for size) objects. Children are also shown a small toy and a matching larger toy and are told that both toys always do the same thing in their respective spaces (e.g. they are told that wherever the little toy hides in the little room, that's where the big toy also hides in his big room). On the experimental trials, children watch as the experimenter hides the small toy in the model and are then required to search for the analogous larger toy that has been surreptitiously hidden in the corresponding location in the room. The idea is that only if children interpret the model as a symbol for the room, will they succeed in transferring knowledge from one to the other. To ensure that any difficulties experienced in the room are not due simply to a decayed memory for the target location, children are also taken back to the model and required to retrieve the original toy. A different hiding location is used on each trial.

#### The Dual Orientation Hypothesis

The results from the original study using the scale model paradigm (DeLoache, 1987b) revealed that, whereas 3.0-year-old children are highly successful at retrieving the analogous toy (searching correctly on at least 75% of the trials), children just six months younger perform very poorly (~17%), searching randomly as though they have no basis for knowing the whereabouts of the large toy in the room (DeLoache, 1987b; 1995). The abrupt improvement in performance occurring in children only six months older is especially striking as both groups of children are highly successful at retrieving the original toy in the model; differences in memory for the target location therefore cannot account for the younger children's difficulty retrieving the analogous toy in the room. So why do the younger children have such trouble transferring their knowledge of the target location from the model to the room? DeLoache's theory, known as the Dual Orientation Hypothesis, is that the younger children's difficulty stems from their

inability to take a dual stance to the model or to interpret it, not only as an object in-and-of-itself, but also as a representation of the room. So compelling is the model as an object in its own right, that the younger children are unable to see through it to the space it represents. Consequently, knowledge of the target location in the model is not brought to bear in searching for the analogous toy in the room (DeLoache, 1987b; 1991; 1995; DeLoache & Marzolf, 1992).

Support for the Dual Orientation Hypothesis comes from a number of experiments using diverse methodologies. In one set of experiments, instead of witnessing the hiding event in the scale model, the target location was pointed out on a photograph or line drawing of the room (e.g. DeLoache & Burns, 1994; DeLoache, 1987b; DeLoache, 1991; DeLoache & Marzolf, 1992; Dow & Pick, 1992) or by showing children a videotape of the hiding event in the room (Troseth & DeLoache, 1998; 1999; DeLoache et al., 1998). In contrast to their poor performance with the scale model, 2.5-year-olds were highly successful with the picture and video versions of the task, searching successfully on 72%-79% of the trials. According to the authors, the advantage of pictures and video is that they are of little interest as objects, serving primarily as representations of something else. They point out that in most western homes even very young children have experience with picture book reading in which the depicted object, and not the medium, is the primary focus (DeLoache, 1987b; 1995; DeLoache & Burns, 1993; 1994). In a sense then, pictures and video do not pose the challenge of dual interpretation as children interpret them primarily (if not exclusively) in terms of what they represent.

A similar rationale was used in a second set of experiments (DeLoache, 1990a; 1993; 1995; 2000). The reasoning in one study was that if interpreting the model as an object precluded 2.5-year-olds from appreciating its symbolic function, then decreasing



its salience as an object should lead to improved performance. To test this notion, the model was housed within a puppet theatre framework and a clear window was placed in front so that children could not come into contact with the model or its contents. The experimenter stood behind the set-up and simply pointed out the hiding location. The idea was to create psychological distance between children and the model by distancing them from the model physically. Another study tested the converse -- that increasing the salience of the model as an object would prove deleterious to the normally successful 3.0-year-olds. To this end, children were allowed to play with the contents of the model for ten minutes prior to administering the standard task. The results were consistent with the predictions generated by the Dual Orientation Hypothesis; improved performance by the younger children in the former study (54 % vs. 28%, DeLoache, 2000, Experiment 2a; 48% vs. 13%, DeLoache, 2000, Experiment 2b, for the window and no window groups respectively) and decreased performance by the older children in the latter study (44% vs. 75% for the playing experience with the model and the standard task respectively, DeLoache, 2000, Experiment 3; see also DeLoache, 1990a; 1993; 1995; DeLoache & Burns, 1993).

A different manipulation was used in another experiment where an attempt was made to eliminate the need for a dual representation of the model by duping 2.5-year-old children into believing that the model and the room were one and the same. Children were introduced to a miniature troll doll and its little room (the model). They were then told of a device that could "magically" enlarge or shrink the room and the doll. A demonstration followed during which they waited behind a curtain, listened to pre-recorded mechanical-sounding noises and saw flashing lights emanating from beyond the waiting area. A few minutes later children emerged and were surprised to find an identical but full-sized room in place of the model. On the experimental trials



that followed, children watched as the experimenter hid the small doll in the scale model, waited while the “machine” enlarged the model and the doll, then searched for the larger doll in the emergent room (on subsequent trials the hiding space alternated between the room and model so that only one “shrinking” or “enlargement” was needed). The results were dramatic; 2.5-year-old children searched successfully for the analogous toy on 76% of the trials (DeLoache, 1995; DeLoache, Miller & Rosengren, 1997; DeLoache & Smith, 1999; Marzolf, 1996). Although children searched in the analogous space, just as they would on the standard task, believing it to be the same object as the original space (only transformed in size) effectively eliminated the need to interpret the model symbolically and thus led to searching successfully.

Taken together, the results of the above experiments provide support for the Dual Orientation Hypothesis. Manipulating the salience of the concrete properties of the model influenced the ability to interpret it in terms of the room; whereas increasing the level of salience proved deleterious to the performance of the normally successful 3.0-year-olds, decreasing the level of salience led to improved performance by 2.5-year-olds. The younger children’s performance also improved substantially when the need to represent the model as a symbol was effectively removed i.e. by convincing them that the model and room were the same thing. The results therefore provide support for the notion that successful performance on the standard model task requires that children respond not only to the concrete attributes of the model, but also to its abstract, representational function.

#### Factors that Influence Task Performance

Numerous subsequent studies have shown that even when children achieve “representational insight” or the realization of the relation that holds between the model and the room, their knowledge is still relatively fragile. For one thing, representing the

relation between the model and the room is subject to rapid decay. Uttal, Schreiber & DeLoache (1995) administered the model task to 3.0-year-old children using the standard procedure with one exception—after witnessing the hiding event in the model, children were required to wait 20 seconds, 1 minute or 5 minutes before they were permitted to search in the room. All children received the three delays in one of three orders (20 seconds, 1 minute or 5 minutes first). The results revealed a dramatic effect of order. Children who received the 5 minute delay first performed extremely poorly on subsequent trials even after a delay of only 20 seconds. In contrast, children who received the 20 second delay first continued to outperform the children in the other groups after the 2 minute and 5 minute delays (although in this group as well there was a negative correlation between performance and delay time). The performance of children who received the 2 minute delay first was similar to the 5 minute delay first group suggesting that, after the longer delays, children appeared to forget about the relevance of the model for guiding their search in the room (Uttal et al., 1995, Experiment 1). This interpretation derives support from the finding that children benefited from receiving a reminder of the target location in the model (e.g. by being allowed to retrieve the original toy first or simply to see the model again) prior to searching in the room (Uttal et al., 1995, Experiments 2 and 3). Thus, although 3.0-year-olds can achieve “representational insight”, they have difficulty maintaining that knowledge, unaided, over even a fairly short period of time.

Performance on the model task is also highly dependent on “iconicity” or the degree of perceptual similarity between the model and the room. For example, compared to when the model, room and their contents are identical (i.e. except for size as on the standard task), 3.0-year-olds’ performance declines markedly when the individual objects in the two spaces are perceptually dissimilar (e.g. when the chair is

covered with blue print fabric in the room but solid brown fabric in the model etc.).

Varying the appearance of the surrounds, however, by having white fabric walls on the room and white cardboard walls on the model, appears to have little effect on performance (DeLoache, 1989b; DeLoache, 1990b; DeLoache, Kolstad & Anderson, 1991). However, as DeLoache points out, it could be that the degree of dissimilarity in that study was simply too subtle to detect the importance of the similarity of the overall space (DeLoache, 1990b). Other researchers have shown that the orientation of the experimental spaces is also critical to success on the task with performance declining significantly when e.g. the orientation of the model is misaligned by 180° with the room (Blades & Cooke, 1994; Bremner & Andreasen, 1998).<sup>1.1</sup>

Perhaps the most compelling demonstration of the role of perceptual similarity is the finding that reducing the physical size ratio of the experimental spaces leads to a dramatic improvement in 2.5-year-olds ability to appreciate the model-room relation.<sup>1.2</sup> Compared to the standard task involving a model and life-sized room (ratio 1:16, different-scale condition) in which their performance was extremely poor (41%, DeLoache et al., 1991), 2.5-year-olds were highly successful (~75%, DeLoache et al., 1991) at finding the analogous toy when the scale difference was reduced and two different-sized models were used (ratio 1:2, similar-scale condition). Although it remains unclear whether the observed effect is due specifically to the reduction of the discrepancy in size, or to other changes inherent in reducing the size ratio-- e.g. the advantage of transferring knowledge between two surveyable spaces (similar scale condition) vs. transferring knowledge from a surveyable space to a surrounding space

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<sup>1.1</sup> The role of the similarity of the configuration of objects in the model and the room has also been investigated. However, as the relevant studies are central to the main question addressed by the research reported in this dissertation, they are reviewed in depth in the introduction to Experiment 1 which is reported in following chapter.

(different-scale condition) or transferring knowledge between things that belong to the same category (two models in the similar scale condition) vs. things that do not belong to the same category (a model and a room in the different-scale condition, DeLoache et al., 1991), the effect is compelling particularly as 2.5-year-olds who first receive the similar-scale condition are subsequently able to pass the standard model task (Marzolf & DeLoache, 1994). Taking the results from the physical similarity studies together, it seems clear that the more a novel symbol resembles its referent, the more likely children will be to recognize that they are related and thus transfer knowledge between them.

The younger children's improved performance on the standard model task following success on the similar-scale task raises another important factor influencing the ability to achieve "representational insight"—experience. A number of studies have shown that previous experience with a relatively easy version of the model task leads to greater success with a more difficult version than would otherwise be obtained. In the research by Uttal and his colleagues described above, 3.0-year-old children who received the short delay of 20 seconds between the hiding and searching events performed significantly better after the 2 minute and 5 minute delays than those children who received the longer delays first (Uttal et al., 1995). Three-year-olds' performance when the objects in the model and room are perceptually dissimilar (a task they usually find challenging, see above) also improves significantly following experience with the standard task in which the objects in the two spaces are perceptually similar (Marzolf & DeLoache, 1994, Experiment 2). And children aged two and a half years who receive the picture or video versions of the task subsequently succeed on the standard version of the model task which they typically find very difficult (DeLoache, 1991, Experiments 2

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<sup>1,2</sup> "Physical size ratio" refers to the ratio of the area of the two spaces.

and 3; Marzolf & DeLoache, 1996, Experiment 2; Troseth & DeLoache, 1998, Experiment 1a).

As mentioned above, experience with the model task in the similar-scale condition facilitates 2.5-year-olds' ability to succeed on the standard (different-scale) task (Marzolf & DeLoache, 1994). This effect has proven extremely robust lasting one day and even one week later even when the different-scale task was administered in a different location, using different materials and different experimenters. These results have been interpreted to suggest that the observed transfer effects are not context-dependent but rather are more generalized and therefore reflect an abstract understanding of symbol-referent relations (Marzolf, Pacha & DeLoache, 1996). Experience with symbols thus appears to contribute to a predisposition to interpret a novel object or event in terms of what it stands for (see for e.g. DeLoache, 1995 for a discussion of this point). Although the possibility of transfer occurring across different symbols (i.e. symbols that do not share the same referent as in the picture, video and model studies) or symbol systems has yet to be explored empirically, the results from the transfer studies with scale models suggest that experience with symbols may be a powerful developmental mechanism for symbolization more generally.

Another variable that appears important for early symbolization is the amount of instruction children receive about the relation between a symbol and its referent. Previous work has shown that three year old children require explicit instruction as to the parallel between the model and the room to succeed on the task. This involves a lengthy introduction to the experimental materials including taking the individual, miniature objects from the model, holding them up beside their larger counterparts in the room and pointing out their correspondence (see DeLoache et al., 1991; Marzolf, 1996). Omitting these explicit instructions proved extremely deleterious to the ability of

3.0- and even 3.5-year olds to appreciate and exploit the model-room relation (DeLoache, 1989a, Experiment 4; DeLoache et al., Experiment 1, 1999). Although 4.0-year-old children appear to succeed in spite of these reduced instructions (DeLoache et al., Experiment 1, 1999), it is not until at least five years of age that children achieve a spontaneous, verbalizable appreciation of the relevance of the objects and events in the model for guiding their search in the room in the absence of any instruction whatsoever about their relatedness (DeLoache et al., Experiment 2, 1999). Thus, even when a novel symbol and its referent are highly perceptually similar, children younger than five years of age still require some degree of explicit instructional support to interpret one in terms of the other.

Empirical efforts to improve 2.5-year-olds' performance on the model task by providing enriched instructions have yielded mixed results. Labeling the individual hiding locations on the experimental trials, even repeated labeling in addition to asking children to indicate the target object immediately after the hiding event on each trial (to reinforce the target location), effected little improvement (DeLoache, 1989, Experiment 3; Solomon, 1997a). However, there is some indication that the nature of the instructions might be critical for 2.5-year-olds as children who were told explicitly that the model was constructed expressly for the purpose of showing them where to find the hidden toy in the room performed significantly better (although still not especially well) than a control group who received the standard instructions (mean performance for the former and latter groups was 42% and 15% respectively; Sharon, 1999a, 1999b). Very young children therefore benefit from instructions that assist in conveying the intended function of the model; when this is explained explicitly, even 2.5-year-olds begin to catch on to the importance of the hiding event in the model for guiding their search in the room. Note that this finding underscores the importance of perceiving the



communicator's *intention* that the model be interpreted in terms of its representational function included in the definition of a symbol provided above. The main point to be made regarding the role of instructions on the model task, however, is that the general developmental pattern points to an age-related decrease in the amount of explicit instructions required to interpret an object symbolically.

It is worth noting that the various factors described in the above summary of previous research—iconicity, experience, instructions—interact to influence children's success on the model task. Thus, high levels of one factor can bolster children's performance against the deleterious effects of low levels of another factor. For example, increasing the iconicity between the model and the room (by reducing the size ratio to 1:2) helps 3.0-year-olds to achieve "representational insight" even when the explicit matching of corresponding items is omitted from the instructions. Children in the similar-scale condition performed significantly better (63%) than a control group who also received the reduced instructions but participated in the different-scale condition (19%, DeLoache et al., 1999, Experiments 1 and 3). And the observed age-related decrease in the amount of instruction required to transfer knowledge from the model to the room also suggests that gains in experience with symbolic materials during the preschool years helps to buffer performance against the adverse effects of minimal instructions (DeLoache et al., 1998, Experiment 2). Multiple factors, in combination, therefore influence whether or not young children will achieve "representational insight" on the model task (see DeLoache, 1995; DeLoache et al., 1999).

Two further points regarding the implications of the research on young children's understanding of scale models are worth mentioning here. The first, is that although children succeed on the model task by three years of age, this initial understanding of the symbolic function of the model is likely to be restricted to an

implicit understanding of the relatedness between the two spaces. Thus, rather than a conscious, verbalizable awareness, the notion of “representational insight” refers to the sudden, tacit realization that an object such as a scale model could stand for something other than itself (DeLoache, 1989a; 2000). It is only with age and cognitive maturity that children develop a more explicit understanding of symbol-referent relations (DeLoache et al., 1999). The second point concerns the broader implications of the scale model research for symbolization more generally. Given the wide variety of symbols and symbols systems to be mastered in a given culture, it is unlikely that acquiring the ability to understand and reason in terms of symbols is a one-time, across-the-board achievement (see e.g. DeLoache, 2000). Instead, each symbol or symbol system is likely to be mastered independently according to the requisite cognitive demands and subject to the influence of a variety of factors that influence achieving “representational insight” (though there is likely to be some overlap in these factors across symbols e.g. iconicity is likely to influence understanding pictures and maps as well as models). The developmental time course of acquiring new symbols should therefore be expected to vary with the nature of the particular symbol or symbol system.

In sum, the research on preschoolers’ understanding of scale models suggests that, unlike adults, the relation that holds between a symbol and its referent is far from transparent to young children; it must be learned, requires explicit instruction at the outset, remains relatively fragile early in development and develops to an explicit, full-blown understanding only over a protracted period of time. And although the age of acquisition of various symbols is thought to vary with the associated cognitive demands, previous experience with symbolic media may render the novice cognizer sensitive to perceiving novel symbol-referent relations.



### An Alternative Interpretation of Success on the Task

The results from the body of work on pre-schoolers' understanding of scale models have important implications not only for the development of symbolization but for the development of representation more generally. Findings from the scale model research have been linked to children's understanding of pretense (Harris & Kavanagh & Dowson, 1997), to the development of a Theory of Mind (Charman & Baron-Cohen, 1995), the role of inhibition in cognitive development (O'Sullivan, Mitchell & Daehler, 1999; *in press*), children's understanding of intention (Dalke, 1998; Tomasello, Call & Gluckman, 1997; Sharon, 1999a, 1999b), and the development of spatial (Bence & Presson, 1997; Blades & Cooke, 1994; Liben, 1998) and analogical (Lowenstein & Gentner, 1998; Lowenstein & Gentner, 2001) reasoning abilities. The scale model studies and the conclusions emerging from that work have thus been highly influential in current thinking about children's representational capacities.

But precisely what does the model task measure? Recall that according to the Dual Orientation Hypothesis, success on the task depends critically on the ability to think about the model as an object in and of itself and also, simultaneously, as a symbol for something other than itself (i.e. for the room). It is the latter representation that facilitates the transfer of knowledge between the two spaces. This rationale has led to interpreting 3.0-year-olds' success on the task as evidence that the ability to interpret the model as a symbol or representation is present by the end of the third year (e.g. DeLoache, 1987b, page 1556; DeLoache, 1989, page 123; DeLoache, 1990, page 114; DeLoache & Marzolf, 1992, page 318). Further consideration of the task demands, however, suggests that this may not be the case.

Indeed, researchers working in two different, but related, lines of research have suggested that the notion that 3.0-year-olds interpret the model as a symbol might over-

estimate their representational abilities. The crux of the issue, for both views, concerns whether success on the task necessitates understanding the model *as a whole* as a representation of the room. The first line of reasoning, proposed by Perner (1991) and supported in a subsequent paper by Lillard (1993), involves distinguishing between correspondence and representation. Whereas correspondence refers to recognizing the similarity between the components of a symbol and its referent, representation (or what Perner calls "meta-representation") refers to the understanding that the symbol *as a whole* is intended to be interpreted in terms of what it stands for. Thus, Perner's (1991) notion of correspondence refers to the similarity of the objects in the two spaces. Establishing object correspondence, or reference for the elements of a symbol, is thought to occur automatically. In contrast, representation requires explicitly representing the higher-order symbol-referent relation (Perner, 1991, pages 78-92). Both Perner (1991) and Lillard (1993) have argued that children could succeed on the model task via the simpler strategy of object correspondence; they could infer the location of the analogous toy by noting the smaller target object in the model (e.g. the small chair), then searching at the matching larger object in the room (e.g. at the large chair). The main point here is that the object correspondence strategy does not necessitate interpreting the model *as a whole* as a representation of the room. Indeed, Perner is not alone in noting this defining feature of representation. For example, based on research on children's understanding of spatial symbols such as maps and aerial photographs, Downs (see also Liben & Downs, 1989) has argued that:

Successful understanding of *any* representation requires a simultaneous appreciation of the holistic "stand for" relationship (the representation as a whole standing for something else) *and* the componential "stand for" relationship (elements of the representation standing for elements of the

referent). (Downs, 1989, p. 79, italics his).

The second line of reasoning, put forth by Blades and Cooke (1994) and Bence and Presson (1997), focuses on the spatial aspect of scale models. A critical feature of models, as with maps and aerial photographs, is that they communicate spatial information. It is the isomorphism between the configuration of items in the model and the configuration of items in the referent space that render scale models useful tools for navigating in the actual space (e.g. Liben, 1998; Lowenstein & Gentner, 2001). These researchers point out that to be credited with understanding the model as a *spatial* representation, children would have to demonstrate awareness of the similarity of the objects (object correspondence) as well as the similarity of the spatial relations between the objects (termed "spatial correspondence") in the two spaces. Previous research suggests that the latter ability does not emerge before four years of age (Bence & Presson, 1997; Blades & Cooke, 1994). The question common to both lines of reasoning therefore is whether 3.0-year-olds' understanding of scale models extends beyond a simple appreciation of the one-to-one mapping of the objects in the model and the room. This possibility gains even further support from work on children's understanding of analogy.

Gentner and her colleagues (Gentner & Ratterman, 1991; 1998; Lowenstein & Gentner, 1998; 2001) have proposed that a "relational shift" occurs in the development of analogical-reasoning. Whereas very young children are only able to detect the similarity between the components of the base and target problems (and their features) in an analogy (e.g. grapefruit and sun), older children become sensitive to the correspondence of the relations between the components (e.g. dog, puppies and cat, kittens). In one study (Gentner & Ratterman, 1991), children were shown a set of objects (base set) and another set of objects (target set) in which two of the objects in

the two sets were identical but occupied different relational positions e.g. A, B, C (base) and B, C, D (target). The experimenter then hid a sticker under one of the objects in the base set and children were required to find a matching sticker in the target set. At issue was whether children searched according to the corresponding object (e.g. B in set 1 and B in set 2) or the corresponding relational position (e.g. B in set 1 and C in set 2). The results revealed that, whereas 3.0-year-olds attended to the objects, 4.0-year-olds searched at the corresponding relational position. Thus, a “relational shift” occurred at four years of age.

Like the Gentner and Ratterman (1991) task, the model task is also presented as a spatial analogy; children are introduced to the two spaces and their contents, then required to reason from the base—the model—to the target—the room. Although on the standard task, the objects in the two spaces occupied the same spatial positions, the cognitive demands of the two tasks are the same; children can use object and/or spatial correspondence to find the hidden sticker or toy. The finding that the 3.0-year-olds in the Gentner and Ratterman (1991) study relied primarily on object matches lends further weight to the claim that they may use the same strategy on the model task. Taking these findings together with the conceptual argument outlined by Perner (1991) and Lillard (1993), and the evidence from the work on children’s understanding of spatial symbols (Bence & Presson, 1997; Blades & Cooke, 1994), suggests that the claim that children represent the model as a whole by three years of age warrants further investigation.

### Overview of Dissertation Experiments

The primary goal of the experiments carried out and reported in the remaining chapters in this dissertation was to investigate the nature of young children’s understanding of scale models. Of particular interest were children’s strategies for

solving the task or, more specifically, the extent to which children rely on object and spatial information to find the hidden toy. The vast majority of this work involved 3.0-year-old children, the age at which children first pass the model task, in an effort to elucidate the nature of children's knowledge of the relation that holds between a symbol and its referent when it is first acquired. Older children were included in one study to explore the developmental consequences of that understanding. To be sure, the experiments reported in the following chapters do not represent the first attempts to explore children's strategies on the model task empirically (as will be seen in the review of the relevant studies in the introduction to Experiment 1). In the present research, however, an attempt was made to go beyond previous findings, introducing innovations to the model task methodology to shed further light on children's strategies and some of the factors that might influence them.

Five experiments were carried out. Experiment 1 focussed on the extent to which children rely on object and spatial information, independently or in concert, to retrieve the hidden toy in the room. To investigate further two key findings from Experiment 1, two follow-up experiments (Experiments 2 and 3) were then carried out. Experiment 4 examined aged-related changes in the nature of children's understanding of the task and included an initial exploration into the role of language in reasoning between the two spaces. A more rigorous attempt was made in Experiment 5 to explore the possibility that language may mediate task success. The thesis concludes with a General Discussion chapter addressing the implications of this research for early symbolization and for cognitive development more generally.

## **Chapter 2**

### Experiment 1: The Role of Object and Spatial Information

As mentioned in the previous chapter, questions regarding the validity of the scale model task have centred on whether success on the task necessitates representing the model as a symbol. At issue is whether 3.0-year-old's understanding is limited to recognizing the correspondence between the objects in the two spaces or whether it extends to appreciating the relation that holds between the model *as a whole* and the room. To address this issue, researchers have investigated the extent to which children rely on the identity of the objects (object information) and their spatial position (spatial information) to find the analogous toy.

To date, the role of object and spatial information on the scale model task has been considered empirically in five published papers. The results of these studies are summarized in Table 2.1. The general idea has been to compare performance on the standard task (both object and spatial information available) to performance in conditions in which *either* object *or* spatial information were available in isolation. The rationale here was that if object correspondence is sufficient to succeed on the task, then children should perform well in conditions in which object information is available and poorly in conditions in which they must rely solely on spatial information to find the analogous toy. The three conditions shown in Table 2.1 were formed by varying the hiding locations and their arrangement in the model and the room (but note that not all studies included all three conditions). In the Control condition, distinctive objects were arranged in the same way in the model and the room. In the Object condition, distinctive containers occupied different spatial positions in the two spaces (e.g. the chair was placed in the front right corner of the model but in the back left corner of the room) and the toys were hidden *with the corresponding objects*. And finally, there were two versions of the Spatial condition: 1). The model and room contained matching sets



Table 2.1

Summary of Results (% Errorless Retrievals) from Studies Investigating the Role of Object and Spatial Information

Reference	Experiment	n	Chance	Condition		
				Control (standard task)	Object	Spatial
a. Blades & Cooke, 1994	Experiment 1 Within Subjects	20	50*	88	-	57 <sup>1</sup>
	Experiment 2 Within Subjects	14	50*	93	-	55 <sup>1</sup>
b. Bence & Presson 1997	Study 1 Within Subjects	16	17	58	-	17 <sup>1</sup>
	Study 2	24	17	-	-	24 <sup>1</sup>
c. DeLoache, 1990	Experiment 1 Within Subjects by Day					
	Between Subjects by Condition on Day 2					
	Day 1	?	20	~78 <sup>»</sup>	-	-
	Day 2	?/2	20	-	~70	~3 <sup>2</sup>
	Experiment 2 Between Subjects	8	20	~81	~35	-
d. Myers & Marzolf, 1999 <sup>†</sup>	Between Subjects	12	25	65	23	25 <sup>2</sup>
e. Marzolf, DeLoache & Kolstad, 1999 <sup>†</sup>	Experiment 1	8	14	-	75	-
	Experiment 2 Between Subjects	8	14	81 <sup>‡</sup>	33 <sup>‡</sup>	-

The three conditions were formed as follows: Control—distinctive objects occupied corresponding positions in the model and the room; Object—distinctive objects occupied non-corresponding positions in the model and the room, toys hidden with the *corresponding objects*; Spatial— 1. identical objects or 2. set-up as in Object condition, toys hidden in the *corresponding spatial position*. Chance level is based on the number of possible hiding locations. \* Based on choosing one of either two distinctive or two identical hiding locations. ? Sample size not given. » Averaged across two groups who participated in different conditions on Day 2. ‡ Instructions as to the similarity between the model and the room were less explicit than on the standard task. † Published after the completion of Experiments 1-4 of this thesis.



of identical objects (Blades & Cooke, 1994; Bence & Presson) or 2). distinctive objects occupied different spatial positions and the toys were hidden *in the corresponding spatial position* (DeLoache, 1990; Myers & Marzolf, 1999; Marzolf, DeLoache & Kolstad, 1999).

A preliminary note of caution is warranted in comparing the results summarized in the table. These studies were conducted in different laboratories, by different experimenters, using experimental designs and methodologies tailored to suit the specific hypotheses. The sources of variation in performance across studies are thus myriad. However, as all studies share a common rationale, basic paradigm and involve children of the same age (3.0-year-olds), the results are presented to provide an overview of the patterns and consistency of performance in previous research. To facilitate interpretation of the results, comparisons across studies and conditions are primarily discussed in terms of deviation from chance. Chance level performance was calculated for each study based on the authors' reports of the number of objects or possible hiding locations in the model and the room. The resulting figures are included in Table 2.1. Thus for example, in the study by Myers and Marzolf (1999) in which children were required to select the correct one of four distinct containers, chance is 25%.

Looking across experiments, performance in the Control condition is reliably above chance. Consistent with the findings from numerous previous studies using the model task (e.g. DeLoache, 1987b; DeLoache, 1989a; Marzolf & DeLoache, 1994; Uttal et al., 1995), when both types of information are available 3.0-year-olds are generally successful at using the model to locate the toy in the room. In contrast, when a strictly spatial solution is required (far right column), performance is similar to chance. Thus, in the absence of object information, children appear to search randomly, as though they

have no basis for determining the location of the hidden toy. At first consideration, the results from the Control and Spatial conditions appear to support the notion that children are solving the model task primarily on the basis of object correspondence. Note, however, that in the primary studies where these results have obtained (Blades & Cooke, 1994; Bence & Presson, 1997), only two conditions were included; performance when both object and spatial information were available was contrasted with performance in a condition with only spatial information. Consequently, the role of object information was only investigated indirectly (by removing it from the task). An important limitation of this approach is that it does not allow for an important alternative possibility—that object and spatial information may contribute jointly to success on the standard task.

This hypothesis has proven difficult to test in part because when Object conditions have been included in the experiments (DeLoache, 1990b; Myers & Marzolf, 1999; Marzolf et al., 1999), the results have been inconsistent. Recall that if children are relying primarily on object correspondence to solve the standard task, then performance in the Object condition should be comparable to performance in the Control condition. This pattern of results obtained in two studies (DeLoache, 1990b, Experiment 2; Marzolf et al., 1999, Experiment 1), however, methodological concerns raise questions as to the validity of those experiments. In one study (DeLoache, 1990, Experiment 2), children first experienced the standard task then, one day later, they participated in the Object condition. Although they were highly successful on the second day (~70%), given that previous research has found substantial evidence of transfer from easy versions to more challenging versions of the model task (e.g. Marzolf & DeLoache, 1994), it seems likely that performance in the Object condition was inflated by prior experience with the standard task. Good performance (75%) obtained in a second study,

in which children did not have experience with the standard task (Marzolf et al., 1999, Experiment 1), however, the absence of Control or Spatial conditions in that experiment precludes adequate comparison groups for interpreting the results. Further cause for caution in drawing conclusions from these findings comes from the results of three additional experiments.

In striking contrast to the above studies, DeLoache (1990b, Experiment 2), Myers & Marzolf (1999) and Marzolf et al. (1999, Experiment 2) found markedly poor performance in the Object condition compared to the Control condition (~35% vs. ~81%, 23% vs. 65% and 33% vs. 81% for the three experiments respectively). Recall that in the Object conditions in these studies, the arrangement of the objects in the model was different from that in the room. Whereas in the Control condition the objects occupied corresponding spatial positions in the two spaces, in the Object condition, they occupied different spatial positions. It could be argued, therefore, that an important consequence of using different layouts in the latter condition was that the model no longer represented the room. This may have created a confusing, indeed unsolvable, situation — children were asked to use as a symbol something that did not faithfully represent its referent. Their apparent difficulty in transferring knowledge from one space to the other in the Object conditions is therefore unsurprising.

Myers and Marzolf (1999) also conflated condition and veridicality of the model as a representation of the room in a recent study in which all three conditions were included. In that study, the configuration of the objects was identical in the model and the room in the Control condition, but not in either the Object or the Spatial conditions. The toy was always hidden with the corresponding object in the Object condition and in the corresponding spatial position in the Spatial condition. Whereas performance was above chance in the Control condition (65%), it was no different from chance in either

of the experimental conditions (23% and 25% for the Object and Spatial conditions). The authors interpreted these findings to indicate that children attend to both types of information to succeed on the standard task. An equally plausible explanation, however, is that the different configurations of objects in the two spaces may have precluded any possibility of interpreting the model as a symbol for the room. Indeed, even if children had succeeded in the Object and Spatial conditions, it remains unclear precisely what good performance in these conditions would have been measuring.

Taken together, the results from the research summarized in Table 2.1 are inconclusive with respect to the nature of 3.0-year-old children's understanding of scale models. In general, children perform well when both kinds of information are available and there is evidence that solving the task with only spatial information is particularly difficult. The extent to which children rely on object information, however, remains unclear. Methodological issues in the available studies cast doubt on the validity of some of the object conditions which might account, at least in part, for the highly variable results. Consequently, it is not possible to determine the extent to which object and spatial information are taken into account on the standard task. Clearly, further experiments including all three conditions and in which the methodological concerns mentioned above were overcome were needed adequately to assess the role of object and spatial information. This was the aim of Experiment 1.

### Overview of Experiment 1

The basic design of Experiment 1 was to compare performance in a Control condition (standard task, spatial and object information available) to two conditions in which either object or spatial information were available in isolation. The Control and Spatial conditions were formed as in previous experiments; in the Control condition, distinctive objects occupied corresponding positions in the model and the room and in

the Spatial condition, identical objects occupied the two spaces (similar to the Spatial conditions in Blades & Cooke, 1994 and Bence & Presson, 1997). The main difference between Experiment 1 and previous studies was in the formation of the Object condition. In contrast to previous studies, the layout of the experimental spaces in the Object condition was identical to that in the Control condition at the outset of the experiment and during the extensive orientation to the experimental spaces. Then, on the experimental trials only, the items in the room were rearranged immediately before children entered the room to search for the analogous toy. Thus, in all conditions the arrangement of items in the two spaces was identical during the familiarization and imitation phases (see below) such that all groups first encountered a scale model that was an exact replica of the room. In this way, the opportunity to interpret the model as a symbol for the room, before administering the experimental trials, was equated across the groups. Furthermore, by including all three conditions in the same experiment, it was possible to determine the extent to which children relied on object, spatial or both types of information to solve the standard task.

Predictions. It was predicted that, if children rely primarily on object correspondence to succeed on the standard task, their performance should be relatively good and similar in the Object and Control conditions and relatively poorer in the Spatial condition. However, if children attend to both object and spatial information, then performance should be poorer in the two experimental conditions compared to the Control condition. Note that in the latter case the means in the two experimental conditions might also differ; if the ability to map spatial relations emerges developmentally later than the ability to map corresponding objects between the two spaces, then performance could be somewhat better in the Object condition.

## Method

### Participants

In all the experiments reported in this thesis, the participants were normally-developing preschoolers recruited through private and council nursery schools and playgroups in Scotland. The samples were predominantly middle class and white although these data were not systematically collected. Written parental consent was obtained prior to participation.

Ninety-six 3.0-year-olds ( $M = 38.4$  months, range = 35.2 - 42.6 months) were tested in Experiment 1. Thirty-two children were randomly assigned to each of three conditions: Control ( $M = 38.6$  months, range = 35.2 - 41.8 months); Object ( $M = 38.3$  months, range = 35.5 - 42.1 months) and Spatial ( $M = 38.5$  months, range = 35.3 - 42.6 months). Each condition comprised equal numbers of boys and girls. In addition, half the children in each condition witnessed the experimenter hide the original toy in the model and searched for the analogous toy in the room and half received the reverse order of spaces (hide in room, search in model). For ease of communication, only the first order will be described here.

### Apparatus and Materials

The layout of the experimental space on the standard task is shown in Figure 2.1a with photographs of the actual scale model used presented in Figure 2.1b. The experimental set-up comprised a portable room (2.43 x 1.52 x 1.88 m) and a scale model replica of the room (.60 x .39 x .38 m, approximately 1/16 the size of the room), constructed of a white polyvinylchloride pipe framework, supporting four opaque, dark-blue fabric walls. A curtain doorway (.54m and .21m wide in the room and model respectively) was created in the centre of the front wall. The curtain door to the room was kept closed during the hiding event such that children were unable to see into the

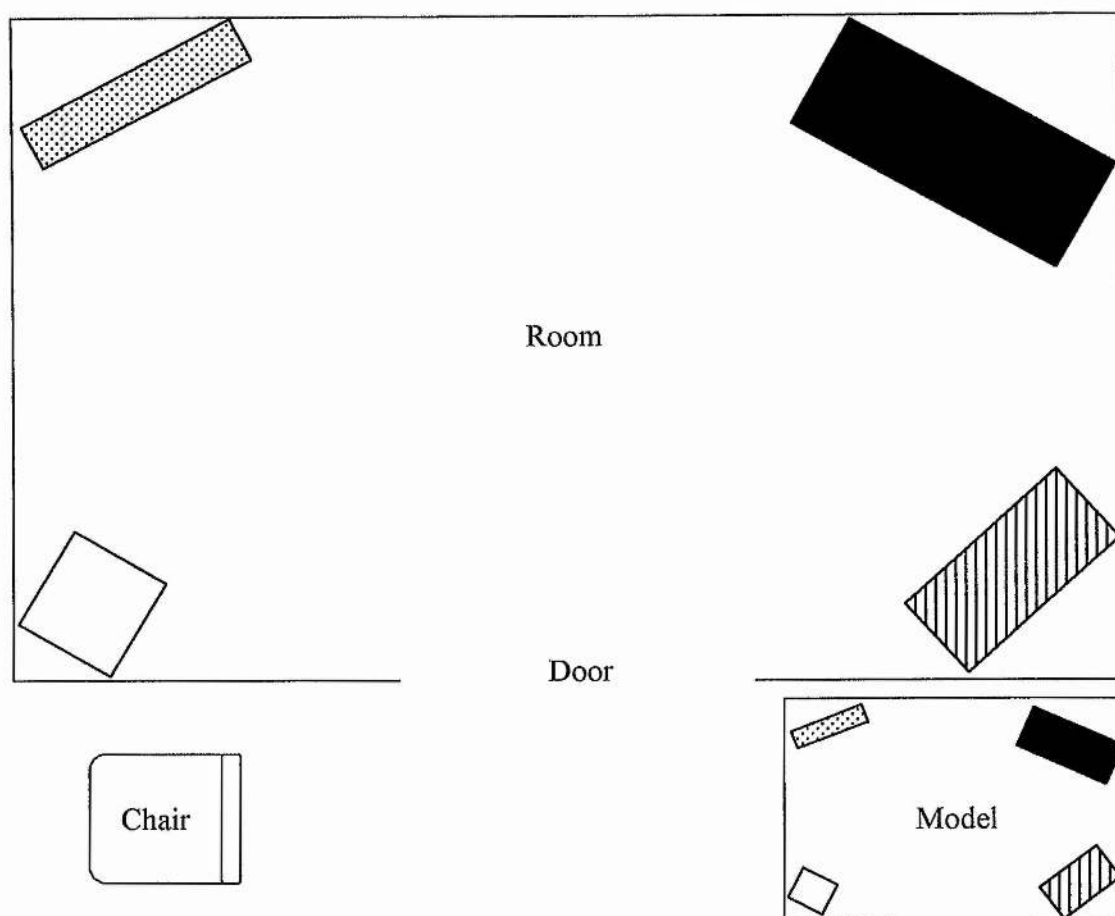


Figure 2.1a Layout of the experimental spaces on the standard task (Control condition). Items in the model were identical (except for size) to those in the room. The drawing is not to scale.



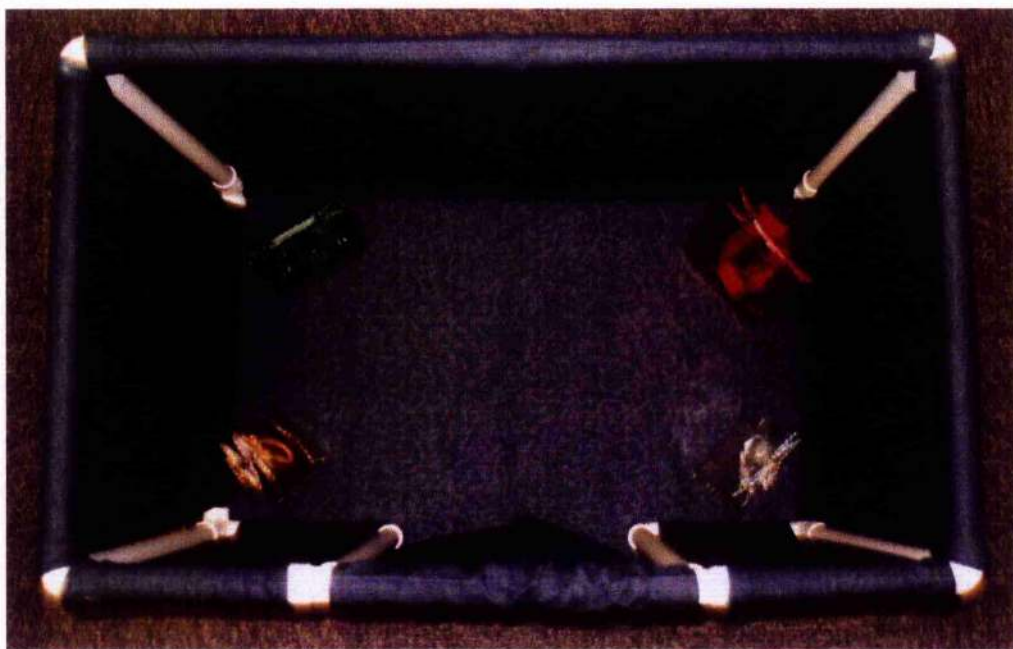


Figure 2.1b Photographs of the Scale Model. The configuration of the hiding containers on the standard task (Control condition) is shown. Children had an aerial view of the model as pictured in the top photograph. A front view of the model is presented in the bottom photograph to provide a sense of the nature of the hiding containers.

model and the room simultaneously. Patterned blue fabric covered the floor area of the two spaces. The model was placed to the right of the doorway, immediately in front of, and in the same orientation as the room. A child-sized chair was located to the left of the doorway facing away from the model.

A hiding container (a “gift bag” constructed of laminated paper and sealed across the top with velcro) was placed in each of the four corners of the room. Miniature replicas of the containers (identical except for size) were located in the corners of the model (see Figure 2.1). Four different types of containers varying in colour, size, shape and type of handle were used. The 4 types of containers were: gold (large: 17 x 10 x 46 cm, small: 6 x 7 x 14 cm), green (large: 33 x 10 x 23 cm, small: 11 x 7 x 7 cm), red (large: 33 x 11 x 46 cm, small: 11 x 7 x 14 cm) and silver (large: 16 x 11 x 33 cm, small: 8 x 7 x 10 cm).

Three conditions were formed by varying the type of hiding containers and their configuration in the model and the room. Figure 2.2 depicts the layout of the two spaces on the first experimental trial by condition. In the Control condition, four visually distinct containers (Green, Red, Silver, and Gold) occupied corresponding corners in the model and the room. In the Object condition, visually distinct containers occupied non-corresponding corners in the two spaces. Thus, on the first experimental trial the gold container occupied the front, left corner in the model and the back, right corner in the room. Furthermore, whereas the configuration of containers in the model was identical to that in the Control condition and remained constant across the four trials, the configuration in the room varied from trial to trial (see below). Finally in the Spatial Condition, identical containers occupied the four corners. The stimuli in the Spatial condition comprised a set of four of one of the types of containers (Green, Red, Silver or Gold) used in the other two conditions with each type being used equally often. Thus,

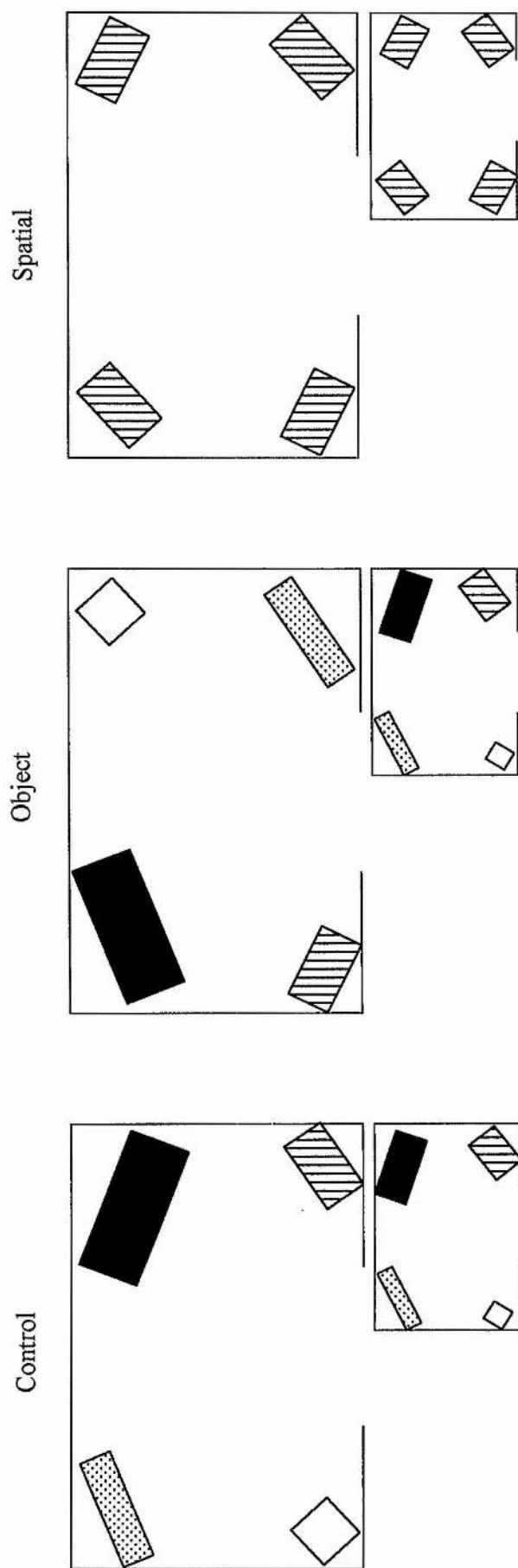


Figure 2.2 Layout of the Scale Model (small space) and the Room (large space) on the First Experimental Trial in Experiment 1 by Condition. In the Control condition, visually distinct objects occupied corresponding corners in the model and the room, in the Object condition, visually distinct objects occupied non-corresponding corners and in the Spatial condition, identical objects occupied the four corners.

four children experienced the Spatial condition with the green containers, four with the red containers, four with the silver and four with the gold. The hiding toys were two plastic ducks measuring 12cm x 15cm and 5cm x 6cm.

### Procedure

Overview. All of the participants in the experiments reported in this thesis were tested by the same female experimenter. Children were tested individually at their nursery school or playgroup venue, in a quiet, well-lit room separate from the children's main play area. The experimenter began by engaging children in casual conversation in the nursery until they appeared comfortable in her presence. She then invited them to accompany her to "a special room to play some games with ducks". To help set children at ease, a member of the nursery staff was permitted to accompany them to the experimental area. The accompanying adult was instructed to stand aside from the experimental setup and to remain silent throughout the test session. The experimenter then administered the testing procedure which comprised three phases; Familiarization, Placement Imitation and Experimental. During the Familiarization Phase, the experimenter introduced children to the two toys and to the experimental spaces and their contents. In the Placement Imitation Phase, the experimenter placed the small toy at a given location in the model and children were required to place the large toy at the corresponding location in the room. Finally in the Experimental Phase, children witnessed the hiding of the small toy in the model and were then required to find the large toy which was hidden at the analogous location in the room. As the procedure forms the basis for all the experiments in this thesis, it is described in detail below and summarized for ease of reference in Table 2.2.

Table 2.2

Summary of the Three Phases of the Procedure

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1. Familiarization Phase

Children were introduced to the two toys, to the model and the room and to their contents. Each smaller object in the model was held up beside its matching counterpart in the room and their correspondence was explicitly pointed out.

## 2. Placement Imitation Phase\*

Children watched the experimenter place the small toy in front of one of the containers in the model and were then invited to place the large toy in the analogous location in the room. The procedure was repeated for two to four trials using a different location on each trial.

## 3. Experimental Phase\*

Children watched the experimenter hide the small toy inside a container in the model (hiding event). Next, they waited on the chair while the experimenter hid the analogous larger toy in the corresponding location in the room. They were then invited to enter the room to search for the analogous toy (Symbolic Retrieval). Finally, they were taken back to the model to find the original toy (Memory Retrieval). Only children's first search attempts were scored although they were allowed to continue searching until they retrieved the hidden toy. The procedure was repeated for four trials using a different location on each trial.

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\*In all the experiments reported in this thesis, half the children made inferences from the model to the room, i.e. they witnessed the experimenter place (Placement Imitation Phase) or hide (Experimental Phase) the small toy in the model and were then invited to place or search for the large toy in the room, and half received the reverse order of spaces. Only the first order is described in the table for clarity.

Familiarization Phase. The session began with an extensive orientation during which the experimenter introduced children to "Little Duck" (LD) and "Big Duck" (BD), the model (referred to as "Little Duck's Room") and the room (referred to as "Big Duck's Room"). The experimenter pointed out that both ducks had "some interesting things" in their rooms. She then held up each item in the model in turn, handed it to children and encouraged them to open it. Assistance was provided if necessary. The procedure was then repeated for the items in the room. This was done to demonstrate that the items were containers and to ensure that children were efficient at unsealing the velcro closures. To underscore the correspondence between the model and the room, she then took the items from the model into the room, held them up individually beside their matching counterparts and pointed out the similarity between the pairs of items. At no time did the experimenter label the containers (e.g. by colour or size).

Placement Imitation Phase. Next, the experimenter led children back to the model and briefly outlined the procedure for the placement imitation trials. She began by holding up the two ducks together and explaining, "These two ducks always do the same thing. Whatever LD does in LD's room, that's what BD also does in BD's room". She continued, "I'm going to put LD somewhere in LD's room and then you can put BD in the same place in BD's room. Remember they always do the same thing". On each imitation trial the experimenter said, "LD's going to sit right here (placing LD in front of one of the containers). Can you help BD do the same thing in BD's room?". She opened the door to the room and encouraged children to enter. If they failed to place BD correctly, they were taken back to the model and reminded of LD's location. The reminder was repeated a second time if necessary after which the experimenter helped children to place BD at the correct location in the room. Children were scored as



correct only if they placed BD at the target location on their first attempt. The imitation trials were administered to a criterion of two-in-a-row correct or to a maximum of four trials. The placement locations were randomly selected and different on each trial. The purpose of the Placement Imitation trials was to emphasize the correspondence between the two spaces and between the actions of the toys in their respective rooms.

Experimental Phase. Four experimental trials followed immediately. Each trial comprised three parts: a hiding event, Symbolic Retrieval and Memory Retrieval. Once again, the experimenter explained the procedure for the upcoming trials. She began by reminding children that both ducks always do the same thing. She then explained, "I'm going to hide LD somewhere in LD's room. Then while you wait on that chair (pointing to the chair), I'm going to put BD in the same place in BD's room. Then you can find BD. Are you ready to play?".

Each trial began with children witnessing the experimenter hide LD inside one of the bags saying, "LD is going to hide right here". Next, she directed children to sit on the chair, facing away from the model.<sup>2.1</sup> Once again she reminded children that both ducks always do the same thing. The experimenter took care to hide BD in the target container while standing in the centre of the room such that children could not use the sound cue produced by opening and closing the velcro closure to locate BD in the room. Children were then invited to find BD (Symbolic Retrieval). If they were unsuccessful on their first search attempt, they were permitted to continue searching until they eventually found BD. This was done to maintain children's motivation to

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<sup>2.1</sup> Recall that half the children in each condition witnessed the hiding event in the room. For these children, the experimenter hid the small toy in the model while they waited on the chair. To ensure that children could not observe the events in the model, the experimenter knelt at the left side of the model with her back towards the chair (occluding children's view of the model) and kept her hands inside the model while hiding the small toy. Thus, even if children turned around while seated on the chair, it was not possible for them to witness the hiding of the analogous toy.



search for BD on subsequent trials and to encourage successful and unsuccessful children alike. Finally, to ensure that poor performance on the Symbolic Retrievals was not due to simply forgetting the location of the original toy, children were returned to the model and required to retrieve LD (Memory Retrieval). Once again if they did not succeed on their first search attempt, they were encouraged to continue (as above) until they eventually retrieved LD. The procedure was repeated for four trials using a different hiding location (selected randomly, without replacement) on each trial.

The same procedure was used for all three conditions with the exception that, in the Object condition, after hiding BD in the appropriate container and before permitting children to enter, the experimenter re-arranged the objects in the room. The arrangement of items (starting from the black left corner and rotating clockwise) in the room on trials 1-4 were: 1) Red, Gold, Silver, Green; 2) Silver, Green, Gold, Red; 3) Gold, Silver, Green, Red and 4) Silver, Gold, Red, Green.<sup>2.2</sup> Thus in the Object condition, the arrangement of objects in the model and the room was the same during the Familiarization and Imitation Phases but different during the Experimental Phase.

The procedure was videotaped. Performance was scored live and checked against the videotapes for accuracy.

### Results

The data from five children (all boys) were excluded from the analyses; four due to experimenter error and one for looking into the room while the experimenter hid the analogous toy (seen on videotape). The results are therefore based on 91 children; 30 in

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<sup>2.2</sup>Note that on each trial the relative positions of the containers were different in the two spaces. This was done to rule out the possibility that children might succeed by forming and a "cognitive map" of the layout in the model and re-aligning it with the layout of the room.

the Control condition (16 girls, 14 boys), 29 in the Object condition (16 girls, 13 boys) and 32 in the Spatial condition (16 girls, 16 boys). On each trial, children were awarded one point if they searched correctly on their first attempt.<sup>2,3</sup> The same scoring system was used for the Symbolic Retrieval and Memory Retrieval trials to yield two scores ranging between zero and four for each child. Mean scores for each task and condition were tabulated then converted to percentages to illustrate the results more clearly and to facilitate comparison to previous studies.

Figure 2.3 shows the results for each task by condition. Overall, performance on the Symbolic Retrievals was more impaired by removing object information (Spatial condition) than by disrupting the symmetry of the spatial relations in the model and the room (Object condition). The means for the Symbolic Retrievals were 57% (SD = 38.2), 47% (SD = 31.6) and 36% (SD = 27.6) for the Control, Object and Spatial groups respectively. All of the group means were significantly different from chance (25%, for selecting the correct one of four hiding locations),  $t(29) = 4.54$   $p < .0001$  for the Control group,  $t(28) = 3.82$ ,  $p < .001$  for the Object group and  $t(31) = 2.24$   $p < .03$  for the Spatial group. Importantly, across conditions, children were very good at finding the original toy. Mean performance on the Memory Retrievals was 80% (SD = 24.91) for the Control group, 78% (SD = 28.62) for the Object group and 70% (SD = 30.28) for the Spatial group. Thus, any differences between conditions on the Symbolic Retrievals could not be attributed to differences in memory for the target location.

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<sup>2,3</sup> Searching was defined as opening a container for inspection. However, several children were observed to pick up and shake a container, only sometimes choosing subsequently to open it. Since children could make judgements as to the presence of the toy on the basis of the weight of the container, a conservative approach was taken and instances of shaking a container, whether or not children then proceeded to open it, were scored as searching. It is interesting to note that children often held the container up to their ear while shaking it as though to listen for any sound made by the hidden toy. However, as no sound was emitted by the toy, the strategy of "weighing" the container, though cleverly employed, was not itself acknowledged as useful.



The data were subjected to a 2 (Task; symbolic retrieval, memory retrieval) x 3 (Condition; control, object, spatial) x 2 (Sex) x 2 (Hiding Space; model or room) analysis of variance (ANOVA). The results revealed main effects of Task,  $F(1, 79) = 61.61$ ,  $p < .0001$ , and Condition,  $F(2, 79) = 3.27$ ,  $p < .04$  which were consistent with the above interpretation of the results in Figure 2.3. Performance was significantly better on the Memory Retrievals compared to the Symbolic Retrievals and post hoc analyses on the Symbolic Retrieval means revealed that compared to the Control condition, children performed significantly worse in the Spatial condition ( $p < .04$ , Scheffé) but not in the Object condition ( $p > .64$ ). These findings indicate that object information was essential to task success. Note, however, that the difference between the means in the Control and Spatial conditions was also non-significant ( $p > .28$ ) suggesting that removing either type of information resulted in statistically similar levels of performance. Although the difference between the means in the Control and Object conditions did not reach statistical significance, the lack of statistical significance between the means in the Object and Spatial groups suggests that neutralizing spatial information may have had some impact on children's ability to find the analogous toy.<sup>2,4</sup> The suggestion here is that while object information may be essential, spatial information may also contribute (to some extent) to success on the standard task. The remaining significant effects in the ANOVA, helped to clarify the basis for this intriguing finding.

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<sup>2,4</sup> The data were also analyzed on the basis of individual performance. Children were classified as "passing" or "failing" according to whether they had successfully retrieved the analogous toy on their first attempt on at least three out of four trials. The number of "passing" children was 16 (53%), 10 (34%) and 5 (16%) for the Control, Object and Spatial conditions respectively. Comparing the number of successful children across conditions revealed the same pattern of results as in the ANOVA; compared to the Control condition, significantly fewer children succeeded in the Spatial condition ( $p = .01$ ) but not in the Object condition ( $p = .19$ ), however, the difference between the Object and Spatial conditions was also non-significant ( $p = .14$ , Fisher's exact tests).

The ANOVA also revealed a main effect of Sex,  $F(1, 79) = 3.82, p < .05$ , favouring girls, and interactions of Task, Condition and Hiding Space,  $F(2, 79) = 3.35, p < .04$ , and Task, Sex and Hiding Space (approaching significance),  $F(1, 79) = 3.62, p < .06$ , which were subsumed by a four-way interaction of Task, Condition, Sex and Hiding Space,  $F(2, 79) = 3.86, p < .03$ . To elucidate the nature of the four-way interaction, the means for each condition are shown by Sex and Hiding Space for the Symbolic Retrievals in Figure 2.4 and for the Memory Retrievals in Figure 2.5. The results for each task are discussed in turn.

Symbolic Retrievals. Separate  $2(\text{Sex}) \times 2(\text{Hiding Space; model, room})$  follow-up ANOVA's were carried out for the Symbolic Retrieval data in each condition. In addition, each sex by hiding space sub-group mean was compared to chance (25%, as children were required to select the correct one of four containers). For the Control condition (top plot in Figure 2.4), there were no statistically significant effects in the ANOVA; boys and girls performed similarly and performance was unaffected by whether the hiding event occurred in the model or the room. Note, however, that although the ANOVA did not reveal an interaction between sex and hiding space, comparing the means to chance revealed that boys' performance was above chance when they witnessed the hiding event in the model ( $M = 63\%; t(5) = 2.67, p < .05$ ), but not in the room ( $M = 47\%; t(7) = 1.99, p < .09$ ) and that for girls this effect was reversed ( $M = 47\%, t(7) = 1.51, p > .18$ , for the model;  $M = 72\%, t(7) = 2.93, p < .02$  for the room). Although the overall Control group mean of 57% is significantly better than chance ( $t(29) = 4.54, p < .0001$ ), it is worth noting that it is somewhat lower than expected for 3.0-year-olds' who typically achieve at least 75% on the standard task (e.g. DeLoache, 1987; DeLoache, 1991; DeLoache et al., 1991; see also DeLoache, 1995). One reason for the relatively lower group mean could be the distribution of the ages of

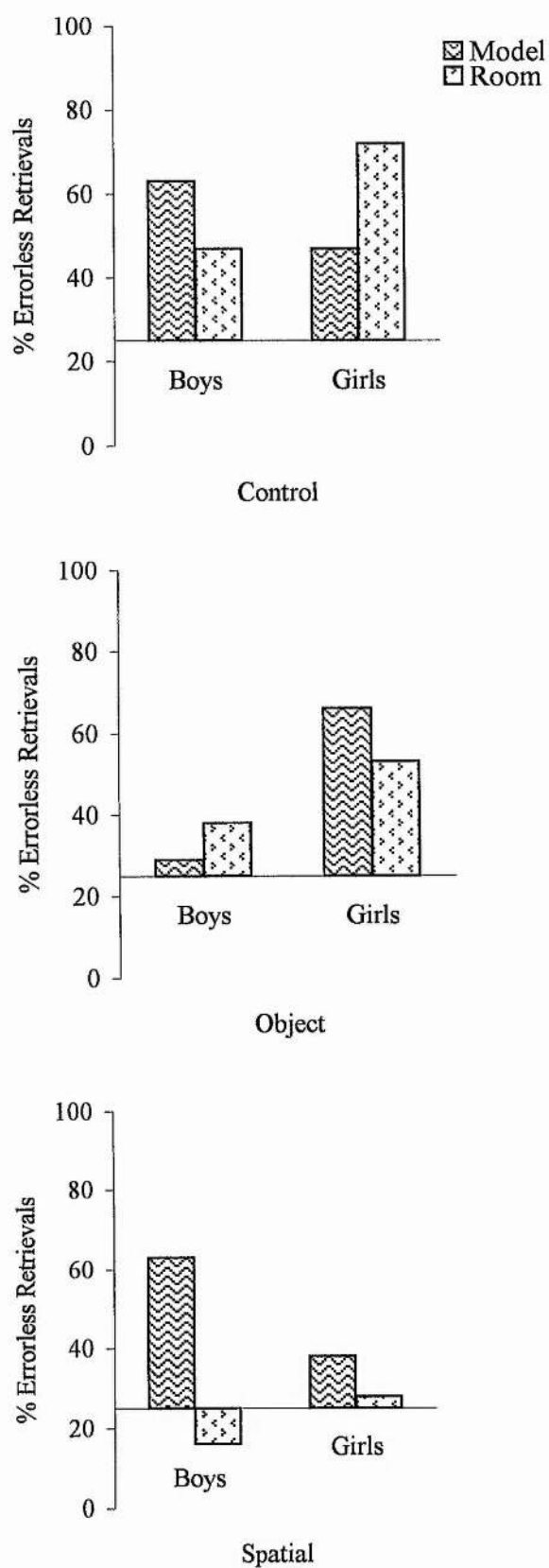


Figure 2.4 Symbolic Retrieval Results for Experiment 1 by Condition, Sex and Hiding Space. The axes in the figures intersect at chance (25%).

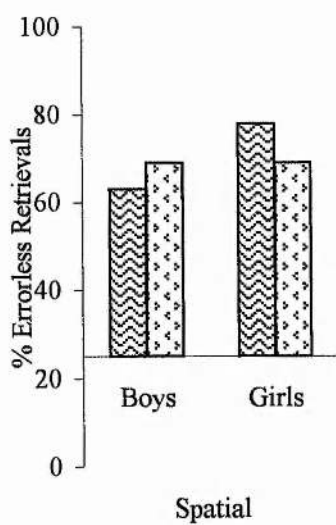
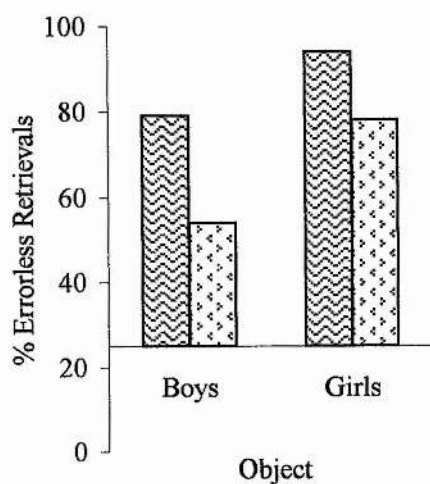
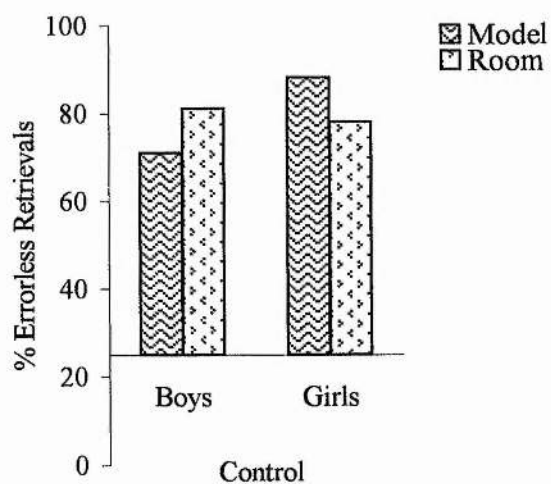


Figure 2.5 Memory Retrieval Results for Experiment 1 by Condition, Sex and Hiding Space. The axes in the figures intersect at chance (25%).



the children in the present sample. Recognizing the model-room relation has been thought to be an all-or-none affair with success on the task emerging abruptly around the third birthday (DeLoache, 1989, Experiment 2). While the mean age of children in Experiment 1 (38.5 months) was highly similar to that of previous studies (38.0 months on average), it is possible that a substantial proportion of children in Experiment 1 may have been below the "threshold" age for achieving "representational insight" (to use DeLoache's terminology). Indeed, 17% were between 35.0 - 36.0 months and 33% were between 35.0 - 37.0 months of age. A preponderance of very young children in the sample might therefore account for the relatively low group mean. This notion was not supported by the data, however, as the mean ages of children classified as "failing" and "passing" were identical (38.5 months) for the two groups. Furthermore, correlation analyses indicated that Symbolic Retrieval performance was not significantly correlated with age (Pearson's  $r = .02$ ,  $p > .93$ ) indicating that, within the age group tested in Experiment 1, performance did not improve with age. The relatively low group mean in the Control condition thus could not have resulted from the inclusion of a number of very young 3.0-year-olds in the sample.

Examination of the number of children categorized as "failing" or "passing" the Memory and Symbolic Retrievals revealed that sixteen children passed both tasks, 5 failed both tasks and 9 children (approximately 33% of the sample) passed the Memory task but not the Symbolic Retrieval task. No child conformed to the reverse pattern of passing the Symbolic task but failing the Memory task. Thus, in contrast to previous studies in which a very high proportion of 3.0-year-olds performed well on both tasks (e.g. DeLoache, 1987; 1991), a substantial number of children in the present study remembered the target location but failed to utilize that knowledge to guide their search

in the room. Further consideration of the relatively low group mean in the Control condition is taken up in Experiment 2.

In the Object condition, the ANOVA revealed a significant effect of Sex,  $F(1, 25) = 5.65$ ,  $p < .03$ . Looking at the middle plot in Figure 2.4, it is clear that girls outperformed boys (59% vs. 33%) regardless of where the hiding event took place. Comparing the sub-group means to chance revealed that whereas girls' performance was above chance in the model ( $M = 66\%$ ;  $t(7) = 4.33$ ,  $p < .003$ ) and also in the room ( $M = 53\%$ ;  $t(7) = 3.21$ ,  $p < .02$ ), boys performed poorly in both spaces ( $M = 29\%$ ;  $t(6) = .26$ ,  $p > .81$  for the model and  $M = 38\%$ ;  $t(5) = 1.0$ ,  $p > .36$  for the room). There were no other significant effects in the ANOVA for the Object condition.

Recall that on the experimental trials in the Object condition, the containers in the room were re-arranged immediately before children searched for the analogous toy so that they occupied non-corresponding corners in the two spaces. For example, on trial 2, the gold container occupied the front, left corner of the model but the back, right corner of the room. As the toy was always hidden in the corresponding container, children who searched in the corresponding spatial position would have been scored as incorrect. To determine if children who performed poorly in the Object condition (i.e. boys) had attempted to use the spatial strategy, the locations of children's first searches were examined. The results revealed that searching in the corresponding spatial position occurred on only 12% of the trials; 14 children searched in the corresponding position on 1 of the 4 trials. Furthermore, a chi-square analysis indicated that boys and girls were equally likely to employ this strategy,  $\chi^2(1, N = 29) = .04$ ,  $p > .84$ . Thus, the erroneous use of spatial information is unlikely to account for the difficulty boys experienced in the Object condition.

Finally, for the Spatial condition (bottom plot in Figure 2.4), the ANOVA revealed a main effect of Hiding Space,  $F(1,28) = 12.46$ ,  $p < .001$ , which was subsumed by a Sex by Hiding Space interaction,  $F(1, 28) = 5.54$ ,  $p < .03$ . In general, performance was better when the hiding event occurred in the model ( $M = 50\%$ ) compared to the room ( $M = 22\%$ ), however, the magnitude of this effect was greater for boys compared to girls (difference between means = 47% for boys vs. 10% for girls). Whereas performance was above chance when boys witnessed the hiding event in the model ( $M = 63\%$ ;  $t(7) = 3.97$ ,  $p < .01$ ), but not in the room ( $M = 16\%$ ;  $t(7) = -1.43$ ,  $p > .20$ ), girls' performance did not differ from chance in either space ( $M = 38\%$ ;  $t(7) = 1.87$ ,  $p > .10$  for the model and  $M = 28\%$ ;  $t(7) = .36$ ,  $p > .73$  for the room). The only successful children in the Spatial condition then were those boys who saw the small toy hidden in the model and searched for the larger toy in the room ( $n = 8$ ). The remaining twenty-four children performed as expected (based on previous experiments e.g. Bence & Presson, 1997; Blades & Cooke, 1994) searching randomly in one of the four containers.

Taken together, the analyses of the Symbolic Retrieval data indicate that the notion that children also encode spatial information may be related to a sex-linked difference in the way they approached the task. Whereas girls attended mostly to the identity of the objects, boys appeared to attend more to their spatial location. Furthermore, the object strategy was more robust; girls performed well regardless of the nature of the hiding space, however, boys' were only successful with the spatial strategy when the hiding event occurred in the model. The overall main effect of condition in the initial mixed ANOVA therefore appears to reflect the fact that a larger proportion of children (mostly girls) succeeded in the object condition compared to the spatial condition.

The data were also analyzed to determine whether children showed any improvement over trials. Performance was averaged over Trials 1 and 2 (Block 1) and Trials 3 and 4 (Block 2) separately and a 3 (Condition; Control, Object, Spatial)  $\times$  2 (Trial Blocks; 1 and 2) ANOVA was carried out. The results revealed no effect of Trial Blocks and no interaction between Trial Blocks and Condition. The only significant result was a main effect of condition,  $F(2, 88) = 3.37, p < .04$ , consistent with the effect of Condition in the initial mixed ANOVA reported at the start of the results section. The main point here is that in all conditions, children performed consistently across trials.

Memory Retrievals. The data were analyzed by a series of 2 (Sex)  $\times$  2 (Hiding Space) ANOVAs analogous to those conducted for the Symbolic Retrieval data. As performance was significantly better on the Memory Retrievals compared to the Symbolic Retrievals (see the results from the initial ANOVA for the combined data from the two tasks), comparisons of the sub-group means to chance were not carried out. For consistency, however, the axes in the plots in Figure 2.5 were also made to intersect at chance (25%).

As is apparent in the figure, children performed very well on the Memory Retrievals. Indeed, there were no significant effects from the Sex by Hiding Space ANOVAs for the Control and Spatial conditions (see the top and bottom plots in Figure 2.5). Thus, in two of the three conditions, boys and girls performed similarly regardless of the nature of the hiding space. The exception to this pattern occurred in the Object condition (middle plot) where the ANOVA revealed a trend toward superior performance by girls,  $F(1, 25) = 3.90, p < .06$  ( $M = 86\%$  vs.  $67\%$ ). Note, however, that although boys performed significantly worse than girls on the Memory Retrievals, that their memory for the target location was still relatively good and outstripped their ability to find the analogous toy ( $M = 67\%$  for the Memory Retrievals but only  $33\%$  for

the Symbolic Retrievals,  $t(12) = -2.64, p < .02$ ). Their relatively poorer memory for the original hiding location thus could not account entirely for the difficulty they experienced with the Symbolic Retrievals when the arrangement of the objects in the model was different from those in the room. The ANOVA also revealed a main effect of hiding space indicating superior memory for the target object when the hiding event occurred in the model compared to the room,  $F(1, 25) = 4.08, p < .05$  ( $M = 87\%$  for the model and  $66\%$  for the room). The Sex by Hiding Space interaction was not significant.

### Discussion

In general, the results suggest that children rely primarily on object information to find the analogous toy. Provided the objects were distinctive (as in the Control and Object conditions) children were fairly good at using their knowledge of the target location in the model to guide their search in the room. In contrast, when the objects were identical and a strictly spatial solution was required most children (fully  $75\%$ ) found the task very difficult.

It is important to note that in all three conditions children were very good at remembering the location of the original toy. This finding is critical for interpreting performance on the Symbolic Retrieval task as it indicates that they represented the target location and maintained that representation in memory for the duration of the trial (recall that the Memory Retrieval was administered after completion of the Symbolic Retrieval on each trial). Their difficulty in the Spatial condition therefore could not be attributed to a failure to encode or remember the target location. Instead, the challenge lay specifically in the need to use the spatial information, and only the spatial information, in the model to locate the hidden toy in the room.

The finding that performance was markedly poor when an explicitly spatial solution is required is consistent with previous findings (Bence & Presson, 1997; Blades

& Cooke, 1994) and supports the suggestion that children's understanding of the model-room relation is based primarily on recognizing the similarity between corresponding objects (Bence & Presson, 1997; Blades & Cooke, 1994). There is, however, some indication that spatial information may also contribute to appreciating the parallel between the two spaces. Although the difference between the means in the Control and Object conditions did not reach significance, the decrease in performance in the latter condition was sufficient to render performance in the two experimental conditions (Object and Spatial) not significantly different. That disruption to either type of information yielded statistically similar levels of performance suggests that, at least to some extent, children may also take spatial information into account. The overall pattern of results thus provides the most support for the second prediction for the group means; the identity of the individual objects appears to be essential, however, there is some evidence their spatial position may also facilitate success on the standard task.

Perhaps the most intriguing finding in Experiment 1 was the suggestion that there may be sex-related differences in the way in which children approached the task. The pattern for girls was clear; they performed well in the two conditions in which object information was available (Control and Object conditions) and poorly when it was absent and the task had to be solved spatially (Spatial condition). This suggests that object information was critical to girls' ability to retrieve the large toy in the room. In contrast, although boys performed as well as girls in the Control condition, when spatial information was neutralized and the task had to be solved on the basis of only object information (Object condition), their performance was no different from chance. Indeed, the absence of reliable spatial information even appeared to disrupt boys (but not girls') ability to remember the location of the original toy as they performed worse than girls on the Memory task (a difference that approached significance). Note,



however, that boys' relatively poorer memory for the target location can not account entirely for the difficulty they experienced when searching in the referent space as their memory for the target location in the model was still significantly better than their ability to find the hidden toy in the room. When only spatial information was available (Spatial condition), fully half of the boys performed as well as on the standard task. Taken together, these results suggest that whereas having distinctive objects was important for girls, the availability of useful spatial information was more important for boys' ability to reason between the model and the room.

It is noteworthy that the boys who performed best were those in the Control and Spatial conditions (the two conditions in which spatial information was available) who witnessed the hiding event in the model. In both conditions, their performance was above chance when the hiding event occurred in the model but not when it occurred in the room. One reason for this advantage could be their perspective on the experimental spaces. Even the smallest children were taller than the model which was open at the top and placed on the floor and therefore had an aerial view of the entire space. This may have helped children to place the target location within the spatial context. In effect, the aerial view of the model may have rendered spatial information more salient to children. Placing the target in context would have been more difficult when the hiding event occurred in the room as children stood beside the target location and thus had only a partial view of the layout of the room.

Previous research has shown that experience with an aerial view of a space results in an improved ability subsequently to navigate within the space (Reiser, Droxy, McCarrel & Brooks, 1982; Uttal & Wellman, 1989). Indeed, it has recently been argued that experience with spatial representations such as maps, that typically provide oblique or overhead views, actually facilitates the ability to represent and



reason about space per se (Uttal, 2000). The finding that boys, but not girls, capitalized on this advantage suggests that they may have been predisposed to thinking about the model in terms of its spatial features. In contrast, close proximity to the target location in the room may have underscored girls' attention to the individual objects; their performance in the Control condition was above chance when the hiding event occurred in the room but not when it occurred in the model. Children's perspective on the experimental spaces (an aerial view of the model vs. a front view of the room) thus appeared to underscore different sources of information with different consequences for boys and girls. These results provide further evidence that boys and girls rely on different strategies to solve the task.

In sum, comparing performance across conditions indicates that the nature of 3.0-year-olds' understanding of scale models is based primarily on recognizing the one-to-one correspondence between the individual objects in the model and their matching counterparts in the actual room. The spatial relations between the objects appears to play a relatively minor (but not absent) role in helping children, as a group, to draw inferences from the model about the room. As such, the results are generally consistent with the findings of previous studies (e.g. Bence & Presson, 1997; Blades & Cooke, 1994; DeLoache, 1990b, Experiment 1; Marzolf et al., 1999, Experiment 1). The novel contribution of the results of Experiment 1, however, is the suggestion that the group means may mask individual differences in how children approached the task. More specifically, the results indicate that the extent to which children rely on object and spatial information may be linked to their sex, with girls attending primarily to the contents of the model and boys demonstrating a fledgling ability to interpret the model spatially. As the notion that boys and girls may use different strategies to solve the model task represents a somewhat unusual finding for this line of research, two further

experiments were carried out to clarify the results in Experiment 1. These experiments (Experiments 2 and 3) are presented in the following chapter followed by a general discussion of the broader significance of the combined results from Experiments 1-3.

## **Chapter 3**

## Experiment 2: Investigating the Validity and Reliability of the Standard Task

One potential challenge for interpreting the results in Experiment 1 was that the mean percentage of Symbolic Retrievals in the Control condition (57%) was somewhat lower than the typical mean for 3.0-year-olds' on the standard task (usually at least 75%, see DeLoache, 1987b; DeLoache, 1991; DeLoache et al., 1991; DeLoache, 1995; Marzolf & DeLoache, 1997). Establishing a valid baseline for performance on the standard task was essential for interpreting performance in the experimental groups in Experiment 1 and also for comparing those results to previous findings. It seemed prudent, therefore, to ensure that the relatively lower level of performance in Experiment 1 accurately reflected children's ability to reason between the model and the room rather than procedural differences between the present research and previous studies in which the relatively higher means had obtained (e.g. DeLoache et al., 1991; DeLoache, 2000; Marzolf & DeLoache, 1994; Marzolf, 1996; Marzolf et al., 1999). In Experiment 2, an additional group of children was tested with a version of the Control task modified to minimize the differences between procedures; two major changes and one minor change were implemented.

The two major changes were aimed at reducing the length of the test sessions. Recall that in Experiment 1 children received up to four Imitation Placement trials and were taken back to the model and reminded up to two times on each trial of the location of the original toy. In addition, they were provided with an overview of the procedure prior to commencing the Imitation Placement and Experimental Phases (in the DeLoache studies, children received only one imitation trial and were not provided with overviews of the procedures). These additional measures were designed to assist children in recognizing the model-room relation; however, it is possible that the added demands on children's attention left insufficient cognitive resources for the

experimental trials that followed. Accordingly, in Experiment 2, the number of Imitation Placement trials was reduced to one and only the standard instructions were provided (see below). The minor change was that, whereas in Experiment 1 the model was open only at the top, in Experiment 2 it was open at the top and the front (as in the DeLoache studies, see DeLoache et al., 1991; Marzolf & DeLoache, 1994 for example) to minimize the physical effort required to place or retrieve the small toy.

### Method

Participants. The participants in Experiment 2 were 8 girls and 8 boys ( $M = 38.4$  months, range = 35.3.- 41.2 months) with no prior experience with the scale model task. As in Experiment 1, half the children experienced the hiding event in the model and searched in the room and half received the reversed order of spaces.

Apparatus and Materials. The scale model, room and hiding containers were the same as those used in the Control condition in Experiment 1. The only difference to the apparatus was that in Experiment 2, the front wall of the model was removed.

Procedure. The procedure in Experiment 2 was the same as that for the Control condition in Experiment 1 with two exceptions: 1). Children were given only one imitation trial. If they were not correct on their first attempt at placing the analogous toy, the experimenter provided assistance in placing BD correctly and explained that "now BD and LD are doing the same thing". 2). The experimenter omitted explaining the procedure to children at the beginning of the Imitation and Experimental phases. Immediately after the Familiarization Phase, the experimenter placed the small toy at a randomly selected location in the model saying, "Look, LD is going to *sit* right here". She then invited children to place the large toy in the corresponding location in the room. Similarly, immediately following the Imitation Placement trial, the experimenter hid the small toy inside one of the containers saying, "Look LD is going to *hide* right

here." She then instructed children to wait on the chair while she hid the large toy in the analogous place in the room. Finally, children were invited to find the large toy. As in Experiment 1, children were reminded on each trial that both toys always do the same thing.

In summary, there were three differences between the Control conditions in Experiments 1 and 2. In Experiment 1, children received up to four Imitation Placement trials, the experimenter provided children with an overview of the procedure prior to the Imitation and Experimental Phases and the model was open only at the top. In Experiment 2 (as in the DeLoache studies), children received only one Imitation Placement trial, the overview at the outset of the Imitation and Experimental Phases was omitted and the model was open at the top and also at the front.

### Results

Performance was scored and group means were calculated as in Experiment 1. The data from the Control condition in Experiment 1 were then compared to the data from Experiment 2.

Performance in the two experiments was highly similar. Figure 3.1 depicts the mean level of errorless retrievals by Task and Experiment. The group means were 89%, ( $SD = 20.35$ ) and 80% ( $SD = 24.91$ ) for the Memory Retrievals, and 53% ( $SD = 35.2$ ) and 57% ( $SD = 38.2$ ) for the Symbolic Retrievals for Experiment 2 and the Control Condition in Experiment 1 respectively. As in the Control condition in Experiment 1, the group mean on the Symbolic Retrieval task in Experiment 2 (53%) was above chance (25%),  $t(15) = 3.20$ ,  $p < .01$ , and performance remained stable across blocks of trials,  $t(15) = -1.73$ ,  $p > .104$ . Furthermore, the relatively lower group mean could not have been due to a preponderance of very young children in the sample. The difference

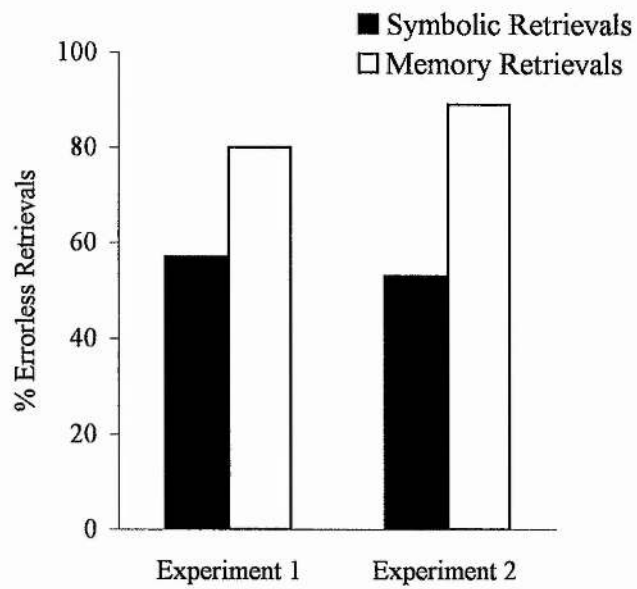


Figure 3.1 Results for the Control Conditions in Experiments 1 and 2.



between the mean ages of children categorized as "failing" and "passing" was only two weeks (38.7 vs. 38.2 months) with the "failing" group being slightly older. Examination of the pattern of passing and failing on the Symbolic Retrieval and Memory Retrieval tasks revealed that only 1 child failed both tasks, 5 children passed both tasks and 10 children (63% of the sample) passed the Memory task but failed to transfer that knowledge to help guide their search in the room (no child passed the Symbolic Task without remembering the location of the original toy).

A 2 (Task; memory retrieval, symbolic Retrieval) x 2 (Experiment; control group in experiment 1, experiment 2) x 2 (Sex) x 2 (Hiding Space; model, room) mixed ANOVA was carried out on the combined data from the two experiments. The results revealed no effect of experiment and no interactions with the experiment variable. The only significant effects were an effect of Task,  $F(1, 38) = 32.60$ ,  $p < .0001$ , indicating that Memory Retrieval performance was superior to Symbolic Retrieval performance, and a Task x Sex x Hiding Space interaction,  $F(1,38) = 5.38$ ,  $p < .03$ . Performance on the Memory Retrieval task was uniformly high; the means for boys and girls for the two hiding spaces ranged between 76%-94% and a follow-up 2 (Sex) x 2 (Hiding Space; model, room) ANOVA revealed no significant effects. As in Experiment 1, an analogous ANOVA carried out on the Symbolic Retrieval data also returned no significant effects, however, the general direction of the sub-group means suggested that boys performed somewhat better when the hiding event occurred in the model (66%) compared to the room (48%) and that the reverse pattern held for girls (45% vs. 61% for the model and the room). The means for boys and girls in Experiment 1 were 63% and 47% for the model and 47% and 72% for the room. The analogous means in Experiment 2 were 69% and 44% for the model with both groups achieving 50% for the room. The means from the two experiments are thus highly similar with the exception that girls in

Experiment 2 did not appear to derive a benefit from witnessing the hiding event in the room (but note that even here, the means were in the same general direction).<sup>3.1</sup> The

Task x Sex x Hiding Space interaction in the mixed ANOVA thus appeared to reflect the fact that the pattern of means for the sex by hiding space cells was different for the Symbolic and Memory Retrieval tasks.

### Discussion

The modifications to the stimuli and procedure in Experiment 2 had no effect on performance on the standard task. The results in Experiments 1 and 2 were highly similar and (with the exception of the relatively lower group means) generally consistent with the results in previous studies. The group mean was above chance, there was no evidence of improvement over trials and, while there were no significant effects of sex or hiding space in the ANOVAs in either experiment, the pattern of the subgroup means, particularly indicating that boys performed best when the hiding event occurred in the model, was also similar in the two studies. Note that, in both experiments, children performed very well on the Memory Task; only one child failed to meet the criterion for "passing" indicating that they accurately encoded and remembered the target location on each trial. Furthermore, there was no indication that the relatively lower group mean was due to the inclusion of a number of especially young children in the sample; the mean ages of children classified as "passing" and "failing" was identical in Experiment 1 and the "failing" group was slightly older (by two weeks) in Experiment 2. However, whereas in most previous studies the majority of 3.0-year-olds readily recognized the relevance of the hiding event in the model for finding the toy in the room, the model-room relation remained opaque for a substantial proportion of

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<sup>3.1</sup> Comparisons of the sub-group means from Experiment 2 to chance were not carried out due to the limited number of observations per cell ( $n = 4$ ) and thus the limited power and meaningfulness of the one sample t-test.

children (33% in Experiment 1 and 63% in Experiment 2) in the Control conditions in Experiments 1 and 2.

It is worth noting that the level of performance in the current research is comparable to performance in studies conducted in other laboratories with children of the same age. For example, Dow and Pick (1992), Bence and Presson (1997) and Myers and Marzolf (1999) report group means of 65%, 58% and 65% respectively on the standard model task. In contrast, the group means in the DeLoache studies have ranged between 75%-92%.<sup>3,2</sup> Although it is difficult to determine the precise source of this variability in performance, given that highly similar procedures were used in different testing locations one possibility could be differences in the populations from which the samples were drawn. For example, regional differences in parenting and early nursery care might influence the amount of experience young children have with symbolic media such as picture books and videos. DeLoache has suggested that experience with a variety of symbols might lead to "symbolic sensitivity" or a general readiness to interpret a novel symbol in terms of what it stands for (DeLoache, 1995, page 100). Indeed, experience with certain types of symbols has been shown to lead to improved performance on more difficult symbolic reasoning tasks (DeLoache, 1991, Experiments 2 and 3 ; Marzolf & DeLoache, 1994, Experiment 3; Troseth & DeLoache, 1999; Experiment 1a; Troseth & DeLoache, 2000). For now, the notion that sociocultural factors might influence early experience with symbolic media, which could in turn affect the ability to acquire new symbols, remains an interesting empirical question for future research. For present purposes; however, given that the results are based on a

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<sup>3,2</sup> Blades and Cooke (1994b) also found that 3.0-year-olds were highly successful on the standard task ( $M = 88\%$  and  $93\%$  for the two experiments, see Table 2.1 in Chapter 2). However, as the methodology employed differed from that of the other studies, and may have contributed to the observed ceiling effect, those findings are not cited here.

large, representative sample ( $n = 46$  for the combined data sets), that the group mean is above chance and comparable to the findings in other laboratories and that the pattern of results is generally consistent with that of previous research, the level of performance in Experiments 1 and 2 is taken as a valid and reliable indicator of the ability of children in the present population to recognize the correspondence between the scale model and the actual room.

### Experiment 3: When Spatial Information is Irrelevant Not Misleading

A second potential challenge for interpreting the results in Experiment 1 concerns the manipulation in the Object condition. It could be argued that by placing corresponding objects in non-corresponding corners in the model and the room (on the experimental trials), rather than being absent, spatial information became misleading. Searching in the corresponding spatial position, which would indicate some understanding of the model as a symbol, would have been scored as incorrect as the toy was always hidden with corresponding objects and corresponding objects always occupied different spatial positions in the two spaces. Although searching in the corresponding spatial position occurred relatively infrequently in the Object condition in Experiment 1 (only 12% of the trials), it is possible that some children became confused by the misleading spatial information (e.g. if they failed to find the toy in the corresponding spatial position on early trials or if they were uncertain about which source of information, object or spatial, to follow) and simply resorted to searching randomly. Boys may have been especially susceptible to confusion arising from misleading spatial information as the results in Experiment 1 suggest that they relied primarily on the spatial position of the target object to solve the standard task. To determine if boys' poor performance in the Object condition in Experiment 1 was due to the presence of misleading spatial information, an additional group of children was

tested in a version of the model task in which spatial location of the objects in the model was irrelevant in the room.

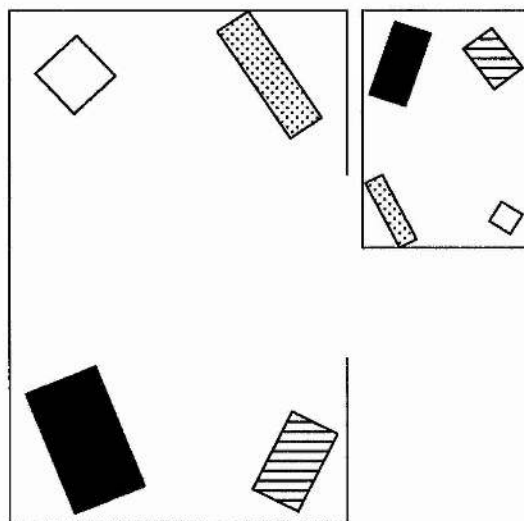
### Method

Participants. The participants in Experiment 3 were 8 boys and 8 girls ( $M = 38.71$  months, range = 35.6 - 41.3 months) who had no prior experience with the scale model task. Equal numbers of boys and girls experienced the hiding event in the model and first searched in the room. The remaining children received the reverse order of spaces.

Apparatus and Materials. The materials were the same as those used in the Object condition in Experiment 1.

Procedure. The procedure was the same as in the Object condition in Experiment 1 with one exception. Figure 3.2 shows the layout of the experimental spaces in the Object condition in Experiment 1 and in Experiment 3. Whereas in the Experiment 1 the objects were re-arranged such that corresponding objects occupied non-corresponding corners in the model and the room, in Experiment 3, the objects in the room were re-arranged in such a way as to leave the corners empty (Empty Corners condition). One container was placed in the middle of each side wall and the two remaining containers were placed in the center of the back wall. Thus, the spatial information was misleading in the Object condition and irrelevant in the Empty Corners condition. As in the Object condition, a different configuration was used on each trial and the order of configurations was fixed across children. The placement of the containers on each trial, from left to right, were: 1) Red, Silver, Green, Gold, 2) Gold, Red, Silver, Green, 3) Green, Gold, Red, Silver, 4) Silver, Green, Gold, Red.

Object Condition  
Experiment 1



Empty Corners Condition  
Experiment 3

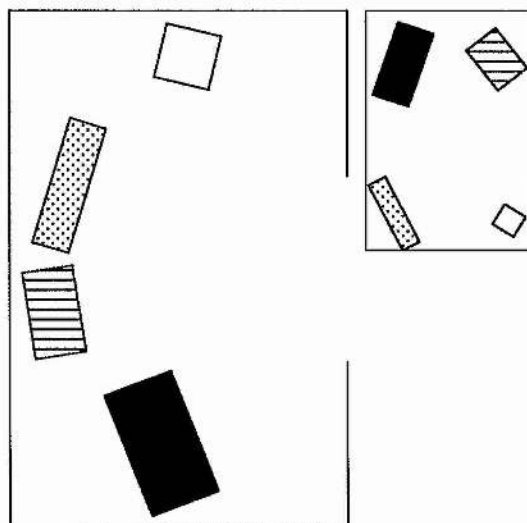


Figure 3.2 Layout of the Scale Model (small space) and the Room (large space) on the First Experimental Trial in the Object (Experiment 1) and the Empty Corners (Experiment 3) Conditions. In the Object condition, visually distinct objects occupied non-corresponding corners in the model and the room. In the Empty Corners condition, visually distinct objects occupied different spatial positions in the two spaces, however, the corners in the room remained empty. Spatial information was therefore misleading in the Object condition and irrelevant in the Empty Corners condition.



## Results

Performance was scored and group means were calculated as in Experiment 1. The data from the Object condition in Experiment 1 were then compared to the data from the Empty Corners condition in Experiment 3.

Figure 3.3 shows the performance of the two groups. The mean percentage of Memory Retrievals was 78% and 83% for the Object and Empty Corners groups respectively and both groups achieved a mean of 48% on the Symbolic Retrievals ( $t(15) = 2.80, p < .01$  for deviation from chance for the Empty Corners condition). As in the Object condition, there was no evidence of improvement over blocks of trials,  $t(15) = -1.32, p > .21$ .

A 2 (Task; memory retrieval, symbolic retrieval)  $\times$  2 (Experiment; experiment 1, object condition; experiment 3, empty corners condition)  $\times$  2 (Sex)  $\times$  2 (Hiding Space; model, room) mixed ANOVA was carried out on the combined data from the two conditions. The results revealed no effect of Experiment and no interactions with the experiment variable. The only significant findings were highly significant effects of Task,  $F(1, 38) = 36.33, p < .0001$ , indicating superior performance on the Memory Retrieval task; Sex,  $F(1, 38) = 15.28, p < .0001$ , favouring girls; and a Task by Sex interaction,  $F(1, 38) = 4.38, p < .05$ . Post hoc analyses revealed that, as in the Object condition in Experiment 1, there was a trend toward superior performance by girls on the Memory Task ( $M = 86\%$  for girls and  $71\%$  for boys,  $t(43) = -1.93, p < .06$ ). The means in the Empty Corners condition were  $88\%$  for girls and  $78\%$  for boys which, although not significantly different,  $t(14) = .78, p > .76$ , were in the same direction as in the Object condition in Experiment 1 ( $86\%$  vs.  $67\%$  respectively). For the Symbolic Retrieval task, girls clearly outperformed boys ( $M = 66\%$  vs.  $29\%$  for the combined data sets,  $t(43) = -4.14, p < .0001$ ). Figure 3.4 shows performance by sex in the Object and Empty Corners conditions separately. In both conditions, girls' performance



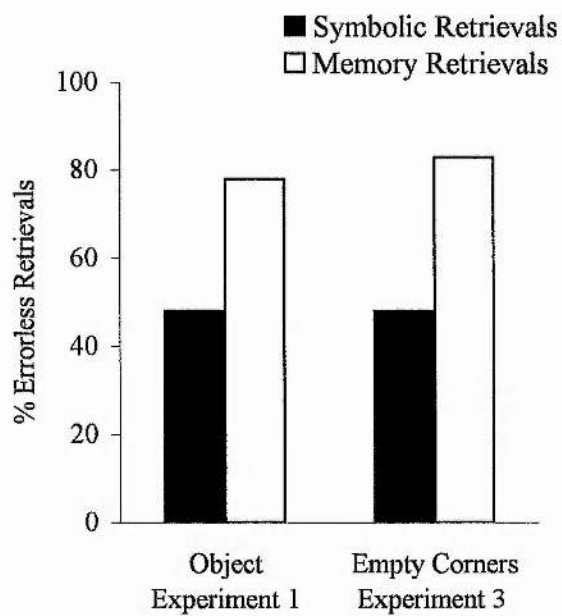


Figure 3.3 Results for the Object (Experiment 1) and Empty Corners (Experiment 3) Conditions by Task.

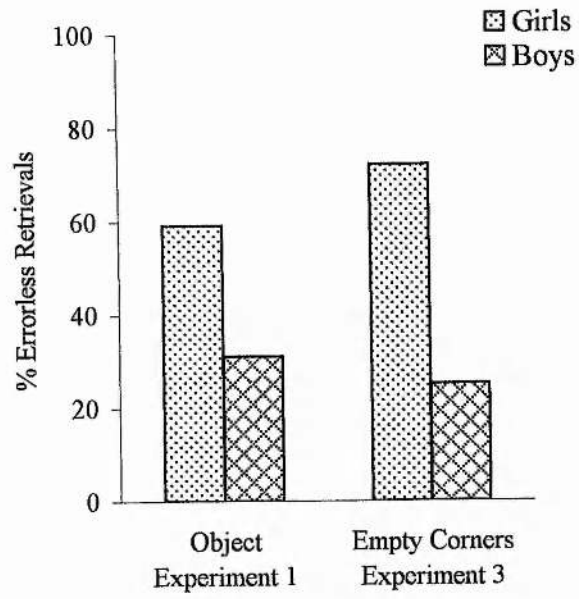


Figure 3.4 Symbolic Retrieval Results for the Object (Experiment 1) and Empty Corners (Experiment 2) Conditions by Sex.

was significantly above chance (Object:  $\bar{M} = 59\%$ ,  $t(15) = 5.37$ ,  $p < .0001$ ; Empty Corners:  $\bar{M} = 72\%$ ,  $t(7) = 6.36$ ,  $p < .0001$ ) but boys' performance was no different from chance (Object:  $\bar{M} = 31\%$ ,  $t(15) = 1.71$ ,  $p > .11$ ; Empty Corners:  $\bar{M} = 25\%$ ). There were no significant effects involving the Hiding Space variable in the ANOVA.

### Discussion

A highly similar pattern of results obtained whether the spatial information in the model was misleading (Object condition) or irrelevant (Empty Corners condition) in the room. The group means were identical, there was no evidence of improvement over trials and, across conditions, disrupting the symmetry of spatial relations between the model and the room had little effect on girls but was highly detrimental to boys', particularly to their ability to find the analogous toy. The misleading spatial information in the Object condition in Experiment 1 thus could not account for the great difficulty boys experienced when retrieving the analogous toy in the room.

An alternative explanation for the observed sex difference could be that the results reflect differences in activity level and the capacity for sustained attention. In the Object and Empty Corners conditions, successful retrieval of the toy required close attention to the new locations of the objects in the room as the configuration of objects was different on every trial. Children who entered the room hurriedly and searched impulsively may have failed to notice the new position of the target object or may have done so only after carrying out their first search (consequently, they would have been scored as incorrect). Boys may have been particularly susceptible to errors of this sort as previous research suggests that they are more impulsive (Block, 1983), active (Harper & Sanders, 1975) and are more frequently diagnosed with attention-related disorders compared to girls (Hynd, Horn, Voeller & Marshall, 1991). The results from a similar study by Marzolf and his colleagues (Marzolf et al., 1999), however, do not support this account.

In that study, as in the Object and Empty Corners conditions, corresponding objects occupied non-corresponding spatial positions in the two spaces and the toy was always hidden with the corresponding object. However, the arrangement of objects in the two spaces was different at the outset of the experiment and the objects in the room occupied the same spatial position on every trial. Thus, children could form a representation of the layout of the room during the extensive orientation then rely on that representation to locate the target object in the room on the experimental trials. In contrast, in the Object and Empty Corners conditions the configuration of the objects in the two spaces was the same at the outset and during the orientation but differed from trial to trial. In these conditions then, children would have to take account of the new configuration in the room and update their representation of the locations of the objects on each trial. It could be argued, therefore, that the Marzolf et al. (1999) study placed fewer demands on children's attentional resources. The results, however, were clear: even with the reduced attentional demands, girls dramatically outperformed boys. The means provided were 73% and 42% for girls and boys for the Control and Object conditions combined; the sex effect was significant and did not interact with condition (see Marzolf et al., Experiment 2, 1999, page 301). Differences in activity level and the capacity to sustain close attention to the task at hand are therefore unlikely to account for the difficulty boys experienced when spatial information could not be used to solve the task. Together with the findings in the Object and Empty Corners conditions, the results from Marzolf et al. (1999) support the claim that whereas girls attend to the individual objects, boys may attend more to the spatial location of those objects to solve the standard task.

#### General Discussion of Experiments 1-3

The results from Experiments 1-3 indicate that, as a group, 3.0-year children rely more on object correspondences than on spatial correspondences when using a scale

model to retrieve a hidden toy in the actual room. In two experiments (Experiments 1 and 2), children performed relatively well when both object and spatial information were available to solve the task, were relatively unaffected by disruptions to spatial information (Object condition in Experiment 1 and Empty Corners condition in Experiment 3) and performed very poorly when object information was not available (Spatial condition in Experiment 1) to solve the task. Although the mean level of performance on the standard task was relatively lower than the typical mean found in previous experiments, this could not have been due to subtle procedural differences between those studies and Experiment 1 as highly similar results obtained in Experiment 2 when every effort was made precisely to match the procedures to those used by DeLoache and her colleagues. That the results in the Control condition in Experiment 1 were effectively replicated in Experiment 2 suggests that the level of performance in the present research can be taken as a valid a reliable indicator of the ability of 3.0-year-old children in the present population to use a scale model to find a hidden toy in a room.

The differences between the means in the five conditions in Experiments 1 to 3 could not be attributed to differences in the ability to remember the identity of the target object vs. its spatial location as, in all conditions and experiments, memory for the target was generally good and significantly better than children's ability to retrieve the analogous toy. Nor do the results reflect differences in the ability to learn the different strategies required for solving the various versions of the task (i.e. relying on object or spatial correspondence, or both) as there was no evidence of improvement over trials in any of the conditions or experiments. Therefore, the results indicate differences in how children interpreted the model at the outset of the experiment. These findings are generally consistent with previous claims that at 3.0 years of age, the identity of the objects predominates over their spatial position for solving the model task. Analyzing

the data from Experiments 1-3 further, however, indicated that this conclusion may have been incomplete: the differences between the means in the five conditions were subserved by sex-related differences in the way children approached the task.

Whereas girls appeared to rely on object cues, boys relied more on spatial information when using a scale model to navigate in the referent space. Whether the spatial location of the objects in the model were misleading (Object condition) or irrelevant (Empty Corners condition) in the room, girls performed as well as in the Control condition, however, boys performance declined sharply and was not significantly better than chance. In contrast, when the objects were identical and a strictly spatial solution was required (Spatial condition), some boys performed well but girls generally performed very poorly. Furthermore, the Object strategy was more robust; provided the objects were visually distinctive (Object and Empty Corners conditions) girls performed very well whether reasoning from the model to the room or vice versa. However, when only spatial information was available (Spatial condition), the only children who were at all successful were those boys who reasoned from the model to the room or when the task context may have facilitated attention to spatial information.

The notion that there may be sex differences in the way in which boys and girls approached the model task is particularly intriguing as it represents a relatively novel finding for this line of research. So why have the majority of previous studies based on the scale model paradigm not found significant effects of sex? The answer seems to lie, at least in part, in the nature of the experiments. Most studies have used between-subjects designs, comparing performance with the standard procedure to performance on various other versions of the task. For example, in one study, the performance of a group of children who received the standard instructions, in which the physical similarity between the model and the room was explicitly pointed out, was compared to

the performance of a second group of children who received a version of the instructions in which explicit comparison of the items in the two spaces was omitted (DeLoache, 1989a; see also DeLoache et al., 1999). Consequently, the analyses were focussed on differences between the group means or on *how well* children performed in the two conditions. Note, however, that as the objects were always distinctive and occupied the same spatial position in the two spaces, the role of object and spatial information were conflated; in all conditions, children could use either (or both) types of information successfully to retrieve the hidden toy in the room. In contrast, by disentangling the roles of object and spatial information in Experiments 1-3, it was possible to shed light on children's strategies, thus shifting the focus to *how* they are solving the task. Consistent with the results of the majority of previous studies, boys and girls performed equally well in the two Control conditions in Experiments 1 and 2, however, their performance in the experimental conditions (Object and Spatial in Experiment 1, Empty Corners in Experiment 3) indicated that they may be predisposed to using different means to achieve the same end. As mentioned in the discussion of the results in Experiment 3, Marzolf et al. (1999) also reported that girls performed significantly better than boys in the Object condition. That similar results obtained in studies carried out in different laboratories and geographic locations (America and the United Kingdom) suggests that the effect of sex in the present research is not an anomalous finding.

Given that the strategy favoured by girls (object correspondence) was more robust than that used by boys (spatial correspondence) and the apparent inflexibility in the type of strategy used (recall that girls performed poorly in the Spatial condition and that boys were markedly unsuccessful in the Object and Empty Corners conditions), one might still expect significant effects of sex to arise occasionally, with repeated sampling. Detecting sex differences in performance statistically has been hampered by



the limited sample size used in most previous studies; the typical experiment comprising eight to twelve children in each condition, usually with roughly equal numbers of boys and girls (see DeLoache, 1989a, Experiments 2-4; DeLoache, 1990a; DeLoache, 1991; DeLoache, 2000; DeLoache et al., 1991; DeLoache et al., 1999; Dow & Pick, 1992; Marzolf & DeLoache, 1994; Marzolf & DeLoache, 1996; Marzolf, Pacha & DeLoache, 1996; Marzolf et al., 1999; Myers & Marzolf, 1999; Troseth & DeLoache, 1996; Troseth & DeLoache, 1998; Uttal et al., 1995). Consequently, there may have been inadequate statistical power to detect any main effects and especially any interactions involving sex. Perhaps for this reason, analyses for sex effects have often been omitted.

It is noteworthy, however, that in spite of limited sample sizes, significant effects of sex have been detected in a number of studies with young children using similar mapping tasks. Moreover, the observed effects share a strikingly similar pattern: without exception, girls outperformed boys (see Blades & Cooke, 1994; Liben, Moore & Goldbeck, 1982; Marzolf & DeLoache, 1994; Marzolf et al., 1999; Troseth & DeLoache, 1999). The results from several studies indicating that, at three years of age, object information is more important than spatial information for solving the model task (Bence & Presson, 1997; Blades & Cooke, 1994; DeLoache, 1991; Marzolf et al., 1999) thus appear to reflect the finding that a larger proportion of children (mostly girls in the present research) favour the object correspondence strategy over the spatial strategy which emerges somewhat later in development.

To the author's knowledge, the results from Experiments 1-3 represent the earliest evidence of a sex difference in strategies for using a spatial symbol to navigate in the referent space raising a number of intriguing developmental questions. Do the sex differences observed in 3.0-year-olds persist with age? Or do they disappear relatively quickly with maturation? What are the cognitive processes that might subserve the

observed difference in which boys and girls approached the model task? Do they change with age? Preliminary investigations into these and related questions are taken up in Experiments 4 and 5 which are reported in the following two chapters.

## **Chapter 4**

#### Experiment 4: The Role of Age, Sex and Language

Perhaps the most intriguing result to emerge from Experiments 1 to 3 was the finding that boys and girls appear to approach the scale model task differently. Although, as a group, 3.0-year-olds relied primarily on object information, children's strategies appeared to be linked to their sex with girls attending more to the objects and boys demonstrating a fledgling ability to interpret the model spatially. Given the relative paucity of sex differences in previous research on young children's understanding of maps and models (Marzolf & DeLoache, 1999), these findings may seem, *prima facie*, as no more than an anomalous, experimental artefact. There are at least three reasons, however, to consider the possibility of sex differences in young children's use of scale models more carefully.

First, as outlined in the previous chapter, it is compelling that in spite of small samples in previous experiments using the standard model task (and thus the limited power to detect potential sex effects), where sex differences have arisen, they tended to favour girls (Blades & Cooke, 1994; Liben et al., 1982; Marzolf & DeLoache, 1994; Marzolf et al., 1999; Troseth & DeLoache, 1999). As previous research converges on the finding that, at the group level, the ability to map individual objects emerges developmentally earlier than the ability to map spatial relations (Bence & Presson, 1997; Blades and Cooke, 1994; DeLoache, 1990b), the advantage to young girls arising in past experiments might be taken as confirmatory evidence that they rely more on the identity of the objects than their male peers. Second, the suggestion of a sex difference in spatial abilities in the pre-school years is not unique to children's understanding of scale models. Indeed, accumulating evidence indicates a male advantage on a variety of spatial tasks including the Mazes subtest of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI, Wechsler, 1967; Fairweather & Butterworth, 1977), mental transformation and rotation (Levine, Huttenlocher, Taylor & Langrock, 1999; Rosser,

Ensing, Gilder & Lane, 1984) and spatio-temporal memory (Orsini, Schiappa & Grossi, 1981). The present data are consistent with these findings in that 3.0-year-olds boys, but not girls, showed some ability to interpret the model spatially. And third, the nature of the observed differences in 3.0-year-olds understanding of scale models is reminiscent of findings in the adult spatial reasoning literature. More specifically, the suggestion that pre-school girls may attend more to the identity of the objects and boys more to their spatial location, bears a striking similarity to claims that whereas adult females rely predominantly on proximal features such as landmarks, adult males rely more on distal, euclidean or geometric properties (direction, distance etc.) of the environment on navigation tasks (e.g. Galea & Kimura, 1993; Miller & Santoni, 1986; Sandstrom, Kaufman & Huettel, 1998; Ward, Newcombe & Overton, 1986). Taken together, these findings lend weight to the plausibility of the notion that there may be individual differences in young children's interpretation of spatial symbols such as scale models and that these differences may be linked to sex.

The important question that arises is whether the apparent predisposition of girls and boys to approach the model task differently at three years of age represents a window onto an initial difference that disappears with maturation or whether it marks a point of divergence that persists with age. Previous findings from research on other aspects of spatial reasoning suggest that it might. For example, recent work on sex differences in mental rotation, long-believed to emerge only in adolescence (e.g. Maccoby & Jacklin, 1974; McGee, 1979), has led researchers to conclude that a male advantage exists as early as the pre-school years and persists across the lifespan (e.g. Linn & Petersen, 1986; Levine et al, 1999; Voyer, Voyer & Bryden., 1995).<sup>4.1</sup> Accordingly, in Experiment 4, children aged four and five years were tested in the same conditions, using the same procedures as in Experiment 1 and the data were then compared with the data from the 3.0-year-olds who participated in Experiment 1. On the

basis of previous findings (e.g. Bence & Presson, 1997; Blades & Cooke, 1994), it was expected that performance in all conditions would improve with age. At issue was whether girls and boys would continue to show an advantage in the object and spatial versions (respectively) of the task.

But what cognitive processes might underlie the observed difference in how male and female preschoolers approached the model task? Taking the lead from explanations put forth to account for the differences in the adult spatial reasoning literature (e.g. Ward et al., 1986), one possibility might be the familiar claim that young girls are precocious for language compared to boys (see Maccoby & Jacklin, 1974). Perhaps girls' attention to the objects reflects a greater tendency to apply a linguistic label to the objects in the model e.g. "the red one", then use that label to guide their search in the room. Such a strategy would succeed whether reasoning from the model to the room or vice versa (although there could be some benefit of witnessing the hiding event in the room; as standing beside the target object during the hiding event may underscore children's attention to the identity of the objects and thus may encourage the use of the labeling strategy; see the discussion section in Chapter 1). To explore the hypothesis that language might underlie girls' superior performance in the Object and Empty Corners conditions in Experiments 1 and 3, in Experiment 4 children received a vocabulary measure (following the scale model task) designed to assess the extent of their receptive vocabularies. The rationale here was that if children use language to

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<sup>4.1</sup> Investigating the possibility that the difference observed at three years of age might persist into later childhood takes on added importance when one considers that an early male advantage in some aspects of spatial reasoning has been linked to male superiority in field independence, geometry and arithmetical reasoning in later years (Geary, 1996; McGee, 1974). Determining the starting point of a continuous divergence in spatial abilities could prove critical for the timing of interventions designed to curtail these later emerging secondary effects.

solve the model task, then lexical ability (an indication of a developing proficiency with language), should be correlated with performance when mapping the individual objects will lead to task success.

Testing the three age groups also afforded investigating age-related changes in the nature of children's representation of the task. DeLoache and her colleagues (DeLoache & Marzolf, 1992) suggest that although children achieve "representational insight" or the abrupt realization that the model may be related to the room around their third birthday, their understanding is limited to an implicit, unconscious, non-verbalizable representation of the task. Thus, even highly successful 3.0-year-olds are said to be unable to articulate their understanding of the model room relation. However, as no relevant data have been reported, it remains unclear whether this construal of 3.0-year-olds' understanding of the model task is based on the observation that very young children do not comment spontaneously on the parallel between the two spaces or if children have been questioned specifically about their understanding of the model-room relation. Subsequent work has shown that by five years of age children's representations have become explicit, conscious and verbalizable (DeLoache et al., 1999) suggesting a shift between three and five years of age in the nature of children's understanding of symbol-referent relations.

To investigate this notion directly, immediately after completion of the model task, the experimenter asked children how they knew where to search for the analogous toy (Knowledge Question). It was hoped that, where children were able to articulate their knowledge, their replies might shed further light on the strategies they employed. The knowledge question was administered to all children whether or not they succeeded on the model task to determine if some children may be able to take a dual stance to the model (i.e. to represent it as an object and also as a symbol) but are somehow unable to use that knowledge to guide their search in the room. It could be argued that asking



“How did you know...?” might have seemed confusing to unsuccessful children, however, this would result in a decreased likelihood of answering the question correctly and thus would work against the finding that some children may have an explicit awareness of the model-room relation but are nonetheless unable to bring that knowledge to bear on their behaviour in the room.

## Method

### Participants

Forty-eight 4.0-year olds ( $M = 50.6$  months, range = 47.2 - 54.8 months) and 48 5.0-year-olds ( $M = 61.9$  months, range = 59.2 - 66.0 months) with no previous experience with the model task participated in Experiment 4. Sixteen children (8 boys and 8 girls) within each age group were randomly assigned to the Control (4.0-year-olds  $M = 50.9$  months, range = 48.1 - 53.3 months; 5.0-year-olds  $M = 62.2$  months, range = 59.6 - 66.0 months), Object (4.0-year-olds  $M = 50.6$  months, range = 47.9 - 53.4 months; 5.0-year-olds  $M = 61.5$  months, range = 59.2 - 64.8 months) and Spatial (4.0-year-olds  $M = 50.3$  months, range = 47.2 - 54.8 months; 5.0-year-olds  $M = 61.9$  months, range = 59.5 - 66.0 months) conditions. As in previous experiments, each condition comprised equal numbers of boys and girls. In addition, half the children in each condition witnessed the hiding event in the model and searched for the analogous toy in the room and half received the reverse order of spaces. The data for the 3.0-year-olds came from the children who participated in Experiment 1 ( $N = 91$ ) the last forty-three of whom had also received the knowledge question and the receptive vocabulary measure (see below).

### Apparatus and Materials

The model, room, containers and toys were the same as those used in Experiment 1. The vocabulary measure was the British Picture Vocabulary Scale –

Second Edition (BPVS- II; Dunn, Dunn, Whetton & Burley, 1997) a widely-used measure of receptive vocabulary developed for use with British children.

### Procedure

Scale Model Task. The experimenter administered the scale model task first using the same procedures as in the Control, Object and Spatial conditions in Experiment 1.

Knowledge Question. After completion of the last experimental trial on the model task the experimenter asked children "How did you know where to look for LD?" (or BD depending on the direction of testing, model to room or vice versa). Children were encouraged to provide verbal responses (those who only gestured initially were told "use your words to tell me") and clarifications were sought as needed. For example, if children indicated, verbally or by gesturing, the object in the model or room that had served as the target on the last trial, the experimenter said, "But LD (or BD) was hiding in a different one every time. How did you know where to find him each time? ".

Vocabulary Measure. Administration of the BPVS-II test followed immediately after the knowledge question. The test was administered according to the standardized instructions (see Dunn et al., 1997); children were required to point to the correct picture, in a matrix of four pictures on a page, that corresponded to a word the experimenter read aloud. The procedure was administered to a criterial number of errors committed within a set of twelve picture-pages (see the BPVS training manual for details). Upon completion of the vocabulary measure, children were praised for their efforts and escorted back to their classroom. The entire procedure was videotaped.

## Results

### Scale Model Task

Performance was scored and mean scores were tabulated as in previous experiments. Figure 4.1 shows the results for the Symbolic and Memory Retrieval Tasks by Age Group and Condition. For all age groups, compared to when both types of information were available to solve the task, performance on the Symbolic Retrieval task was more disrupted by the absence of object information (Spatial condition) than by the removal of reliable spatial information (Object condition). Furthermore, performance on both tasks improved steadily with age although, in general, memory for the location of the original toy continued to outstrip the ability successfully to retrieve the analogous toy. The group means for the Symbolic Retrieval task in the Control, Object and Spatial conditions, respectively, were: 57% ( $SD = 38.24$ ), 47% ( $SD = 31.58$ ) and 36% ( $SD = 27.63$ ) for the 3.0-year-olds; 72% ( $SD = 31.46$ ), 64% ( $SD = 37.60$ ) and 58% ( $SD = 26.95$ ) for the 4.0-year-olds; and 80% ( $SD = 24.53$ ), 75% ( $SD = 28.87$ ) and 61% ( $SD = 31.58$ ) for the 5.0-year-olds. The analogous means for the Memory Retrieval task were: 80% ( $SD = 24.92$ ), 78% ( $SD = 28.61$ ) and 70% ( $SD = 30.27$ ) for the 3.0-year-olds; 86% ( $SD = 22.30$ ), 86% ( $SD = 27.34$ ) and 60% ( $SD = 36.37$ ) for the 4.0-year-olds and 92% ( $SD = 19.83$ ), 97% ( $SD = 12.5$ ) and 77% ( $SD = 21.35$ ) for the 5.0-year-olds. All of the group means were significantly above chance (25%),  $p$ 's  $< .05$ .

A 2 x (Task; symbolic retrieval, memory retrieval) x 3 (Agegroup; 3.0-, 4.0-, 5.0-year-olds) x 3 (Condition; control, object, spatial) x 2 (Sex) x 2 (Hiding Space; model, room) ANOVA was carried out on the combined data for the three age groups. The results revealed main effects of Condition,  $F(2, 151) = 8.69$ ,  $p < .0001$ , Task,  $F(1, 151) = 65.68$ ,  $p < .0001$ , and Age Group,  $F(2, 151) = 10.73$ ,  $p < .0001$ , and a Task by Age Group interaction,  $F(2, 151) = 4.98$ ,  $p < .01$ , confirming the above interpretation of the results presented in Figure 4.1. The effect of Condition on Symbolic Retrieval

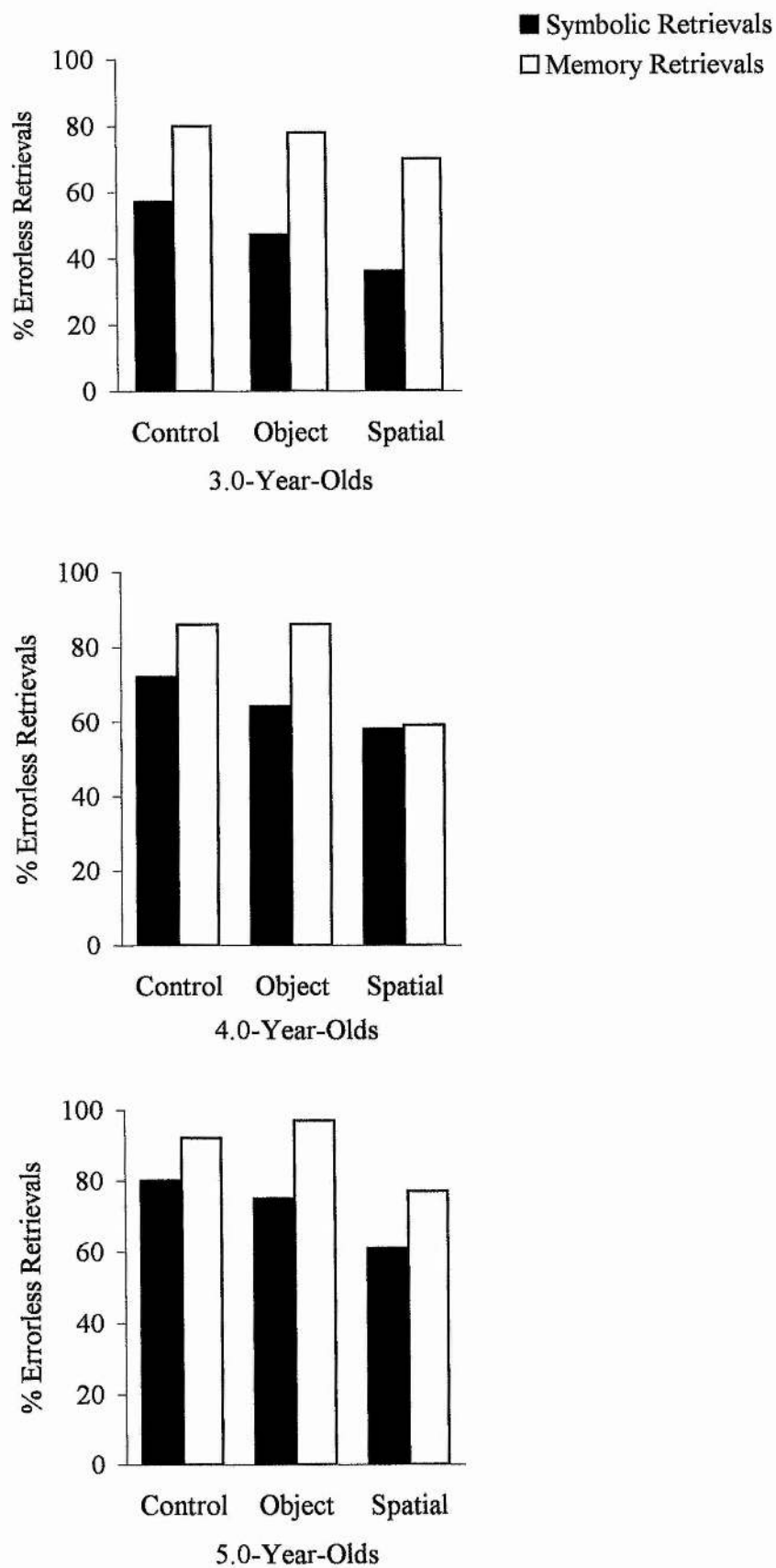


Figure 4.1 Results for Experiment 4 by Task, Age Group and Condition.

performance was generally in keeping with the pattern that obtained for the 3.0-year-olds in Experiment 1; compared to performance in the Control group, performance was significantly worse in the Spatial group ( $p < .0001$ ) but not in the Object group ( $p > .70$ ). Unlike Experiment 1, however, the difference between the means in the Object and Spatial groups in Experiment 4 reached statistical significance ( $p < .01$ , all tests Scheffé).

Performance generally improved with age and was significantly better on the Memory Retrieval Task, however, the pattern of performance across the three age groups was somewhat different for the two tasks. Follow-up analyses revealed that on both tasks, 5.0-year-olds performed significantly better than 3.0-year-olds ( $p < .0001$  for the Symbolic Retrievals,  $p < .03$  for the Memory Retrievals) and that there were no statistically significant differences between 4.0- and 5.0-year-olds ( $p > .54$  for the Symbolic Retrievals,  $p > .12$  for the Memory Retrievals). However, whereas there was no difference between 3.0- and 4.0-year-olds memory for the location of the original toy ( $p > .95$ ), 4.0-year-olds were somewhat better than 3.0-year-olds at using that knowledge to guide their search in the room (a trend that approached significance,  $p < .07$ ; all comparisons Scheffé). The Age Group variable did not interact with any of the other variables in the ANOVA.

The main effects of Condition and Task, as well as a main effect of Sex,  $F(2, 151) = 8.69$ ,  $p < .0001$ , favouring girls, and a three-way Condition, Sex and Hiding Space interaction,  $F(2, 151) = 3.1$ ,  $p < .05$ , were subsumed by a significant interaction of Task, Condition, Sex and Hiding Space,  $F(2, 151) = 3.70$ ,  $p < .03$ . As in Experiment 1, to illuminate the nature of the four-way interaction for the combined data from the three age groups, the results for each Condition are presented by Sex and Hiding Space for the Symbolic Retrieval task in Figure 4.2 and for the Memory Retrieval task in Figure 4.3 and each task is discussed in turn.

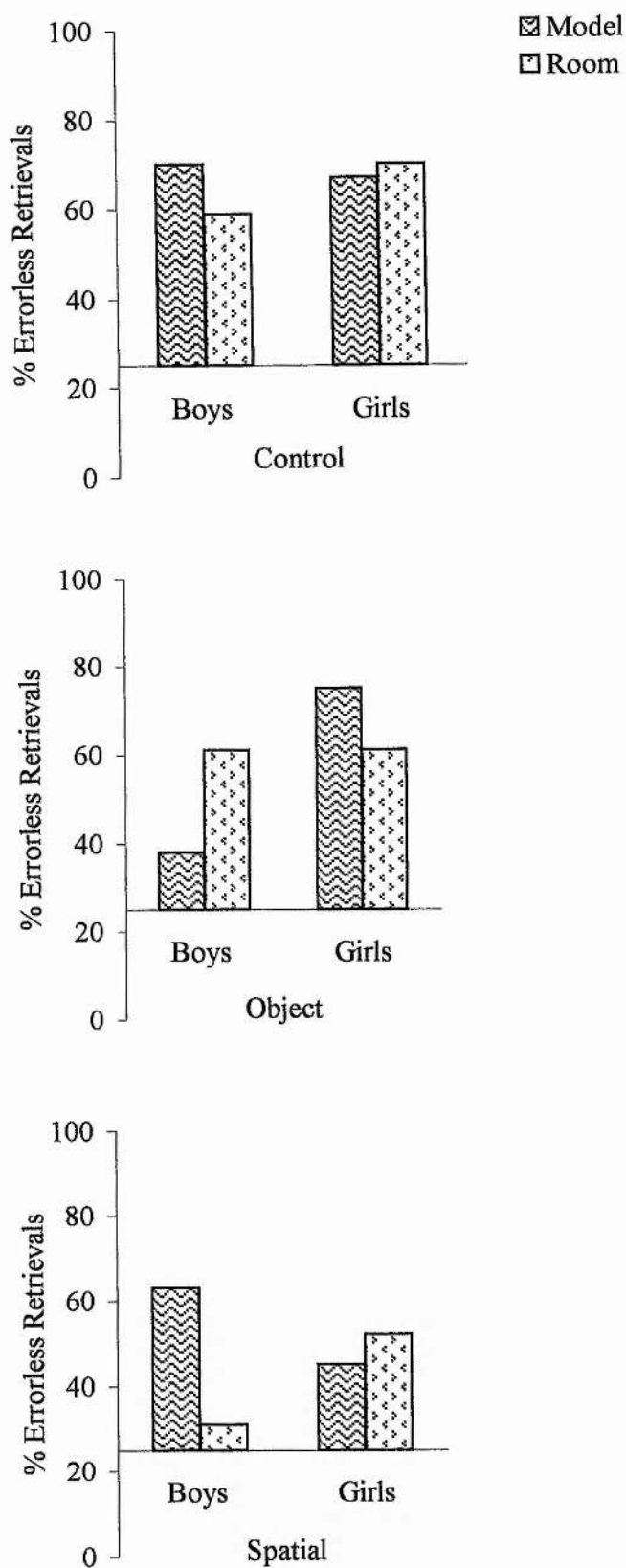


Figure 4.2 Symbolic Retrieval Results for Experiment 4 (collapsed across age group) by Condition, Sex and Hiding space. The axes intersect at chance (25%).

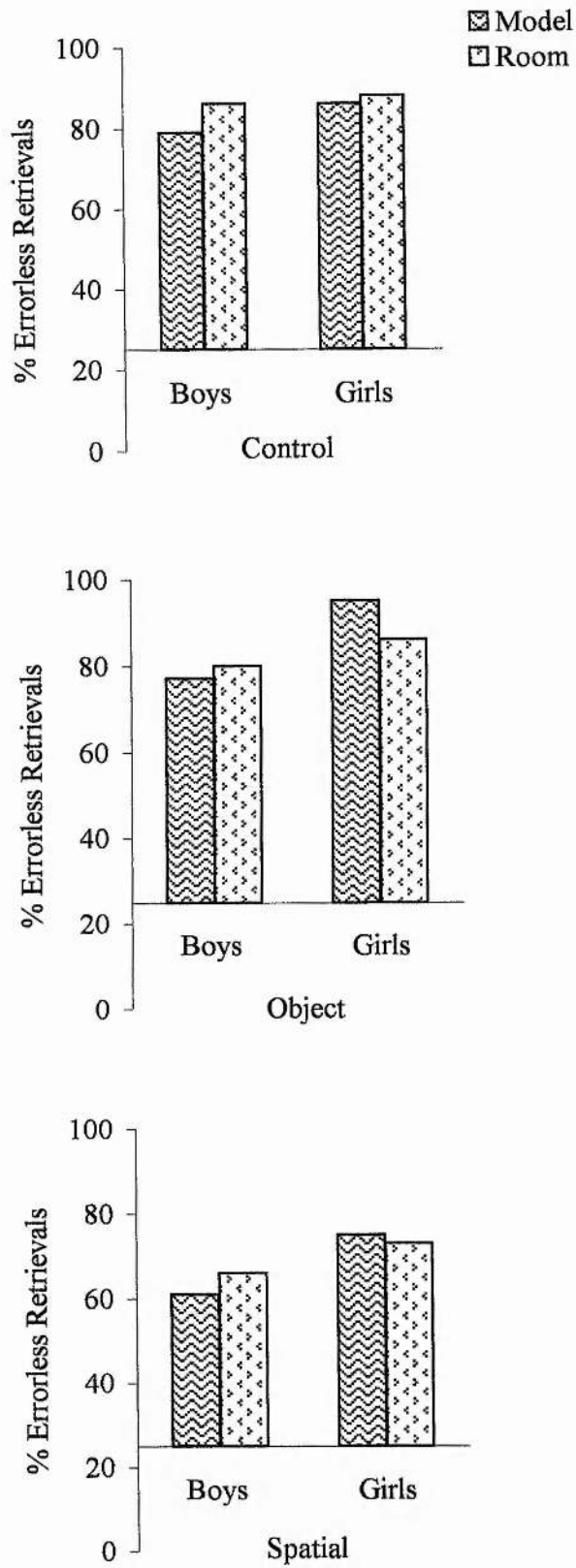


Figure 4.3 Memory Retrieval Results for Experiment 4 (collapsed across age group) by Condition, Sex and Hiding Space. The axes in the figures intersect at chance (25%).



Symbolic Retrievals. A series of 2 (Sex) x 2 (Hiding Space) follow-up ANOVAs was carried out on the data in each condition. The results revealed no significant effects for the Control condition (see Figure 4.2); the top plot in the figure shows that boys and girls performed equally well and that their performance did not vary significantly with the nature of the hiding space. Indeed, comparing the Sex by Hiding Space subgroup means to chance (25% for selecting the correct location out of four possible locations) revealed that performance was always significantly above chance (all  $\bar{M}$ 's  $\geq 59\%$ ,  $p$ -values  $< .001$ ). Recall that in Experiment 1 boys performed best when the hiding event occurred in the model while for girls performance was best when it occurred in the room. That the same pattern did not obtain when the data from the three age groups were combined indicates that the effect of the type of hiding space on boys' and girls' performance on the standard task attenuated with age.

For the Object condition (middle plot in the figure), there was a significant main effect of Sex,  $F(1, 61) = 4.96$ ,  $p < .03$ , favouring girls ( $\bar{M} = 68\%$  and  $50\%$  for girls and boys), and a Sex by Hiding Space interaction,  $F(1, 61) = 4.84$ ,  $p < .03$ ; boys performed significantly better when the hiding event occurred in the room compared to the model ( $M = 38\%$  and  $61\%$  for the model and the room),  $t(30) = 3.27$ ,  $p < .05$ , however, girls performed equally well regardless of the nature of the hiding space, ( $\bar{M} = 75\%$  for the model and  $61\%$  for the room),  $t(30) = -.58$ ,  $p > .57$ . Comparing the subgroup means to chance confirmed that whereas boys' performance was above chance for the room,  $t(14) = 4.16$ ,  $p < .001$ , and not for the model,  $t(14) = 1.37$ ,  $p > .19$ , girls' performance was above chance for both spaces,  $t(15) = 7.30$ ,  $p < .0001$  and  $t(15) = 4.55$ ,  $p < .0001$  for the model and the room. The finding in Experiment 1 (3.0-year-olds only) that girls significantly outperformed boys in the Object condition thus persisted when the data were combined across the three age groups. Indeed, the only difference between the results for the Object condition in the two experiments was that, whereas in Experiment

1 boys performed very poorly, regardless of the type of hiding space (model or room), the results for Experiment 4 suggests an age-related increase in their ability to benefit from witnessing the hiding event in the room.

As with the 3.0-year-olds in the Object condition in Experiment 1, instances of erroneously searching in the corresponding spatial position were relatively infrequent at four and five years of age; only two 4.0-year-old girls committed this type of error, each on two of the four trials, and seven 5.0-year-olds (3 girls and 4 boys) did so on only one trial. Searching in the corresponding location thus occurred on only 6% and 11% of the trials at four and five years of age respectively (the corresponding figure for 3.0-year-olds was 12%). As only four of these errors (6% of the trials at age five) were committed by boys, their continued inferior performance in the Object condition could not be attributed to the misleading spatial information created by placing corresponding objects in non-corresponding corners in the model and the room on the experimental trials.

A different pattern of improvement obtained in the Spatial condition (bottom plot). There was a trend toward a main effect of hiding space, with somewhat better performance when the hiding event occurred in the model,  $F(1, 60) = 2.99, p < .09$  ( $M = 54\%$  and  $41\%$  for the model and the room), and a Sex by Hiding Space interaction,  $F(1, 60) = 6.72, p < .01$ . In Contrast to the Object condition, boys performed significantly better when the hiding event occurred in the model compared to the room,  $t(30) = 3.27, p < .003$  ( $M = 63\%$  and  $31\%$  for the model and the room), while girls' performance was similar for the two hiding spaces,  $t(30) = .58, p > .57$  ( $M = 45\%$  and  $52\%$ ). The ANOVA results were supported by comparisons of the subgroup means to chance; performance was significantly above chance for boys in the model,  $t(15) = 5.48, p < .0001$ , but not the room,  $t(15) = .94, p > .36$ , while girls' performance was above chance for both spaces,  $t(15) = 3.1, p < .003$  and  $t(15) = 3.06, p < .01$  for the model

and the room. Thus, when only spatial information was available, the benefit to boys of witnessing the hiding event in the model that obtained at 3.0-years of age in Experiment 1 (difference between the means for the model and the room = 47%) also obtained in Experiment 4 when the data for 3.0- to 5.0-year-olds were combined (difference between the means = 32%). In contrast, girls' performance did not vary with the nature of the hiding space in either experiment (difference between the means = 10% and 7% for Experiments 1 and 4 respectively).

As in Experiments 1 to 3 the Symbolic Retrieval data were also analyzed to determine whether there was any change in performance over the two blocks of trials (formed by tabulating mean performance on Trials 1 and 2 (Block 1) and Trials 3 and 4 (Block 2)). A 3 (Age Group; 3.0-, 4.0-, 5.0-year-olds)  $\times$  3 (Condition; control, object, spatial)  $\times$  2 (Trial Blocks; 1, 2) ANOVA revealed no effects of Trial Blocks and no interactions with the Trial Block variable. The only significant effects were main effects of Age Group,  $F(2, 178) = 11.22, p < .0001$ , and Condition,  $F(2, 178) = 4.76, p < .01$ , consistent with the pattern in the ANOVA reported at the outset of the results section.

Memory Retrievals. The Memory Retrieval data were subjected to a set of 2 (Sex)  $\times$  2 (Hiding Space) ANOVAs analogous to those carried out on the Symbolic Retrieval data. As is apparent in Figure 4.3, children's Memory for the location of the original toy was very good in all conditions (all  $M$ 's  $\geq 61\%$ ). Indeed, the only significant effect in the ANOVAs occurred in the Object condition where there was a trend towards superior performance by girls,  $F(1, 57) = 3.41, p < .07$  ( $M = 78\%$  and  $91\%$  for boys and girls respectively), in line with the results in Experiment 1. Thus, disrupting the symmetry of spatial information between the model and the room continued to have some impact on boys', but not on girls', memory for the target location. Note, however, that as in Experiment 1, boys' performance in the Object condition in Experiment 4 was very good, and significantly better than their

performance on the Symbolic Retrieval task, (49%),  $t(28) = -4.108$ ,  $p < .0001$ , indicating that their relative difficulty at finding the analogous toy is unlikely to be due to a decayed memory for the target location.

In sum, the pattern of results for the Symbolic and Memory Retrieval tasks in Experiment 4 was generally in keeping with that in Experiment 1 with the differences between the two sets of findings primarily reflecting that performance in all three conditions generally improved with age. The important finding was that the extent to which children relied on object and spatial information was different for boys and girls at all ages. Although both boys and girls improved in their ability to solve the object and spatial versions of the task between three to five years of age, whereas girls continued to rely primarily on the individual objects, boys strategies depended on the contextual support of the hiding space (they performed well when the hiding event occurred in the model, but not in the room when a spatial solution was required and the reverse effect held when the task necessitated mapping the individual objects). As children's responses to the Knowledge Question were also analyzed taking verbal ability into account, the results for the receptive vocabulary task are presented next followed by the results for the Knowledge Question.

### Receptive Vocabulary

Performance on the BPVS-II (1997) was scored according to the accompanying scoring manual (see Dunn et al., 1997) to yield raw scores or the total number of words children understood. A 3 (Agegroup: 3-, 4- and 5-year-olds)  $\times$  3 (Condition: control, object, spatial)  $\times$  2 (Sex)  $\times$  2 (Hiding Space: model, room) ANOVA on children's raw scores revealed a significant effect of Age group,  $F(2, 121) = 23.85$ ,  $p < .0001$ . Post hoc analyses indicated that 5.0-year-olds understood significantly more words than 4.0-year-olds ( $p < .0001$ ) who in turn understood significantly more words than 3.0-year-olds ( $p < .03$ , Scheffé). There were no other significant effects in the ANOVA. Thus within

each age group, children's receptive vocabulary scores did not vary with either sex, condition or hiding space.

Table 4.1 shows the correlation between BPVS-II raw scores and performance on the Symbolic Retrieval task by Age Group and Condition for boys and girls separately. Children's receptive vocabulary scores were significantly, positively correlated with performance on the model task for boys at three years of age,  $r = +.95$ ,  $p < .003$ ,  $n = 6$ , and for girls at five years of age,  $r = +.86$ ,  $p < .007$ ,  $n = 8$ , in the Control condition (Spearman correlations). Ninety percent of the variance in 3.0-year-old boys' performance and 74% of the variance in 5.0-year-old girls' performance was therefore accounted for by children's receptive vocabulary scores. There were no other significant correlations for the Control condition and no significant correlations for the Object and Spatial conditions at any age.

#### Knowledge Question

Of the 139 children who received the knowledge question, the data from two children, one 3.0-year-old girl and one 5.0-year-old boy, were not available due to technical difficulty. Children's responses to the knowledge question were coded by two female assistants who were blind to the hypotheses of the study but familiar with the scale model task. To ensure that the coders were also blind to age and sex and to the direction of testing (model to room or vice versa), the assistants coded transcriptions of children's responses, including brief descriptions of their accompanying actions, which were taken from the videotapes. The transcriptions were coded globally for whether or not they indicated any understanding of the model-room relation. More specifically, the coders were required to decide whether children's responses gave any indication of an understanding that knowledge of the hiding location in one space (e.g. the model) could be used to guide their search for the analogous toy in the other space (e.g. the room). One assistant coded all 137 responses and the second assistant coded 38 (28%),

Table 4.1

Correlations of Receptive Vocabulary Raw Scores and Symbolic Retrieval Performance  
by Age Group, Condition and Sex

		Age Group		
		3.0-Year-Olds	4.0-Year-Olds	5.0-Year-Olds
<u>Condition</u>	<u>Sex</u>			
Control	girls	+0.17 <u>n</u> = 8	+0.58 <u>n</u> = 8	+0.86** <u>n</u> = 8
	boys	+0.95*** <u>n</u> = 6	-0.06 <u>n</u> = 8	-0.20 <u>n</u> = 8
Object	girls	-0.12 <u>n</u> = 8	+0.05 <u>n</u> = 8	-0.06 <u>n</u> = 8
	boys	+0.36 <u>n</u> = 5	+0.51 <u>n</u> = 8	+0.39 <u>n</u> = 8
Spatial	girls	-0.19 <u>n</u> = 8	+0.48 <u>n</u> = 8	+0.09 <u>n</u> = 8
	boys	+0.82 <u>n</u> = 8	+0.53 <u>n</u> = 8	+0.56 <u>n</u> = 8

\*\*\*  $p < .003$  and \*\*  $p < .007$  for Spearman's rho



randomly selected from the original set for the purpose of calculating inter-coder reliability. There was 95% agreement between the two coders. The two disagreements were resolved with discussion. Responses that did not suggest an understanding of the model-room relation were further subdivided according to whether children: 1). provided an incorrect verbal response or 2). said "I don't know" or remained silent. Examples of transcriptions coded as belonging to each of the three resulting response categories-- "Correct Response", "Incorrect Response" or "I don't Know/No Response"-- are provided in Table 4.2.

Seventy-four of the 137 transcriptions came from children who "passed" the Symbolic Retrieval task (i.e. retrieved the analogous toy on their first attempt on at least three of the four trials). Figure 4.4 shows the number of successful 3.0-, 4.0- and 5.0-year-olds who provided the three types of responses to the knowledge question. Three aspects of the figure warrant mention. The first noteworthy aspect is that there was a clear, age-related increase in the number of successful children. The height of the bars in the figure indicates that fourteen 3.0-year-olds (33%), twenty-six 4.0-year-olds (54%) and thirty-four 5.0-year-olds (72%) met the criterion for success. A chi-square analysis on whether or not children succeeded on the task by Age Group was significant,  $\chi^2(2) = 13.37$ ,  $p < .001$ ; follow-up tests revealed no difference between four and five years of age ( $p > .14$ ), a trend toward an increase between three and four years of age ( $p < .06$ ) and a significant difference between the three and five years of age ( $p < .0001$ , Fischer's Exact). Note, however, that the apparent age-related performance improvement could not be attributed to the presence of a few especially competent 4.0- and 5.0-year-olds as the results for the analyses by individuals parallel the pattern that emerged from the analyses of the group means suggesting that performance was superior for the older age groups as a whole.



Table 4.2

Examples of Children's Responses to the Knowledge Question

---

Coding Category

---

1. Correct Response

C: Wherever you put wee duck, I found where BD is.

C: I remembered where baby duck was (analogous toy was BD).

C: Because what LD does in her room, BD does as well. They do the same thing.

C: I just, I just thought.

E: So, what did you think?

C: LD (indicating the model) hides in the same place as BD (indicating the room).

2. Incorrect Response

C: Magic.

E: How did you know which one to look in?

C: (no response).

C: Because he was squeaking (note that the toy did not make any noise).

E: But how did you know which one to look in?

C: Because I heard him go quack, quack.

C: 'Cause you hided him.

E: How did you know which one to look in?

C: 'Cause I just know. 'Cause I'm a big girl.

3. "I don't Know"/No Response

C: I don't know.

C: (No answer).

E: You found him everytime...

C: (nods yes).

E: How did you know which one to look in?

C: (No answer).

E: Can you tell me?

C: (Nods no).

---

Children were asked "How did you know where to look for LD?" (or BD depending on the direction of testing). Transcriptions shown are of the ensuing verbal exchange between the Experimenter (E) and the Child (C).

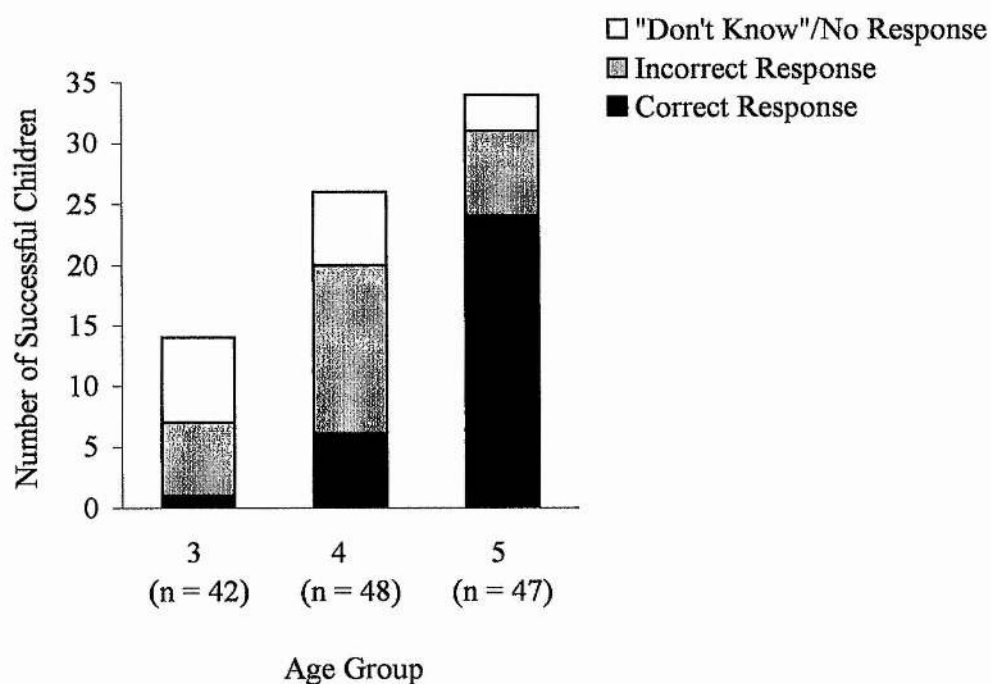


Figure 4.4 The Number of Successful Children in Each Age Group Who Provided the Three Types of Responses to the Knowledge Question. The n's in parentheses indicate the total number of children (successful and unsuccessful) for whom data for the knowledge question were available.

The second noteworthy aspect of the figure concerns the number of successful children who had an explicit and verbalizable awareness of the model-room relation. The black sections of the bars show that one 3.0-year-old (7%), six 4.0-year-olds (23%) and twenty-four 5.0-year-olds (71%) responded correctly to the knowledge question. Thus, whether or not children had an explicit, verbalizable awareness of the model-room relation increased somewhat between three and four years of age (7% vs. 23% of successful children's responses) and more dramatically between four and five years of age (23% vs. 71%). A chi-square analysis crossing the three age groups with whether children provided a correct response (the black sections in the bars) or did not (the white and grey or "I don't know/no response" and "incorrect" sections combined) confirmed this interpretation; there was a significant effect of Age Group,  $\chi^2(2) = 22.23, p < .0001$ . Whether or not children provided the correct response to the knowledge question did not change significantly between three and four years of age ( $p > .39$ ), however, there was a significant increase between four and five years of age ( $p < .001$ ) and between three and five years of age ( $p < .0001$ , Fischer's Exact).

Only five 5.0-year-olds (two in the Control condition and three in the Object condition) made specific reference to a particular strategy--the Object strategy. These responses include: "...I was thinking about that BD will be in the silver one and I can look in the silver one.", "Because I know which colour they were." and "Because it's the same colour". Another child responded "Ummm...because it was in the red box and then I knew it was in each box.". To clarify, the experimenter hid LD in one of the containers (while the child watched) then asked where she should hide BD in the room. The reply was "the same colour". A similar exchange occurred between the experimenter and yet another child who said that the experimenter should hide BD in "the red one", the colour of the target container. The responses of the remaining successful children who correctly answered the knowledge question tended to focus on

the parallel actions of the two toys (see the examples of "correct" responses in Table 4.3).

Whether or not children answered the knowledge question correctly also varied significantly across conditions,  $\chi^2(2) = 8.09$ ,  $p < .02$ . Seventeen of the 27 (63%) successful children in Object condition, 8 of the 30 (27%) successful children in Control condition and 6 of the 17 (35%) successful children in the Spatial condition articulated their knowledge of the model-room relation. Subsequent analyses showed that compared to the Control condition, significantly more successful children answered the knowledge question correctly in the Object condition,  $p < .01$ , but that the difference between the Control and Spatial conditions, and the Object and Spatial conditions, was not significant,  $p > .74$  and  $p > .12$  respectively (Fisher's Exact). Thus, in spite of comparable performance, more children were able to verbalize their knowledge of the model-room relation in the Object condition than in the Control condition. Across the three conditions, twenty successful girls and eleven successful boys answered the knowledge question correctly, a difference which was not significant,  $\chi^2(1) = 2.61$ ,  $p > .11$ . Analyzing the data within each condition separately revealed no effect of sex in either the Control ( $p > .41$ ), Object ( $p = 1.0$ ) or Spatial ( $p = 1.0$ ) conditions.

Recall that whereas successful children's ability to verbalize their awareness of the model-room relation did not change significantly between three and four years of age, there was a significant improvement between four and five and also between three and five years of age. While it is possible that the apparent increase reflects changes in the nature of children's representation of the task (i.e. from an implicit understanding to a more explicit and verbalizable understanding), there are at least two alternative explanations for the observed improvement. The third noteworthy aspect of Figure 4.4, the black and grey sections of the bars, or the number of children who provided any

kind of response (correct or incorrect) to the knowledge question, will be used to address the first of these possibilities.

The first possibility is that the more mature 5.0-year-olds may simply have been more confident and less shy than their younger peers in responding to interrogation by a strange, authority figure. More specifically, the desire to please the experimenter, by providing the correct response, may have been more likely to prevent uncertain 4.0-year-olds than 5.0-year-olds from articulating their understanding of the task. If this were true, then successful 5.0-year-olds would be expected to be significantly more likely to respond to the experimenter's questioning at all (correctly or incorrectly) compared with their younger peers. To test this notion, a chi-square analysis was carried out crossing whether successful children provided any kind of response to the knowledge question (the black and grey sections of the bars combined) or remained silent or said "I don't know" (the white sections of the bars) with the three age groups. Seven of the 14 successful 3.0-year-olds (50%), six of the 26 successful 4.0-year-olds (23%) and three of the 34 successful 5.0-year-olds (9%) remained silent or "said I don't know" to the knowledge question. Although the chi-square result was significant,  $\chi^2(2) = 9.97, p < .007$ , follow-up tests showed that whereas the difference between 3.0- and 5.0-year-olds was significant,  $p < .03$ , the difference between 3.0- and 4.0-year-olds ( $p > .16$ ), and 4.0- and 5.0-year-olds, was not ( $p > .16$  for both comparisons, Scheffé). The important finding here is that, while whether or not children responded to the experimenter did not vary, the ability to answer the knowledge question correctly improved significantly between four and five years of age. Thus, it is unlikely that the observed improvement in children's ability to answer the knowledge question correctly was due simply to the attenuating effects of the demand characteristic of interacting with the experimenter.

The second alternative explanation for the improved ability to verbalize the model-room relation is that the changes reflect increases in vocabulary size. Were younger children less likely to articulate a correct response simply because they had more limited vocabularies? This did not appear to be the case as whether or not children answered the knowledge question correctly continued to be significantly correlated with age group even after taking children's receptive vocabulary raw scores into account,  $r = +.41$ ,  $p < .0001$  (partial correlation).

Finally, it is worth noting that at each age group there were a few children who, in spite of experiencing great difficulty on the Symbolic Retrieval task (i.e. they failed to meeting the criterion for "passing" the task of searching correctly on their first attempt on at least three of the four trials), nonetheless expressed an understanding of the correspondence between the experimental spaces and the actions of the two toys. This group comprised four 3.0-year-olds (2 boys and 2 girls), eight 4.0-year-olds (5 boys and 3 girls) and two 5.0-year-olds (both boys) or 10%, 17% and 4% of the entire sample of 3.0-, 4.0- and 5.0-year-olds (respectively) for whom knowledge question data were available. There were three such children in each of the Control (2 boys and 1 girls) and Object (1 boy and 2 girls) conditions and eight in the Spatial condition (6 boys and 2 girls). The very limited sample sizes precluded formal analysis of these data.

### Discussion

Experiment 4 was designed to achieve three main goals: 1). to determine whether the extent to which boys and girls rely on object and spatial information to solve the model task continues to differ during the pre-school years; 2). to investigate the possibility that girls' superior performance in the Object and Empty Corners conditions in Experiments 1 and 3 might be subserved by a tendency to label the target location and 3). to explore the possibility of an age-related change, during the pre-school years, in the nature of children's representation of symbol-referent relations (i.e.

from an implicit to a more explicit understanding). An overview of the scale model task results for the three ages and conditions is presented first before discussing each goal in turn.

### The Effects of Age and Condition on Performance on the Scale Model Task

Combining the data from Experiments 1 and 4 (i.e. across the three age groups) yielded a pattern of results generally in keeping with the pattern that obtained for the 3.0-year-olds in Experiment 1. For both the Symbolic Retrieval and Memory Retrieval tasks, children showed a marked improvement between three and five, and a non-significant improvement between four and five years of age, perhaps due to ceiling effects. Three and 4.0-year-olds were equally good at remembering the target location in the original space (e.g. the model), however, 4.0-year-olds were somewhat better than their younger peers at using that knowledge to find the corresponding toy in the analogous space (e.g. the room). Thus, there are important gains in the ability to use a spatial symbol such as a scale model to navigate in the referent space during the pre-school period.

It is important to note that these findings represent the only significant effects of age on performance on the scale model task as age did not interact with any of the other variables (Condition, Sex or Hiding Space) in the current Experiment. The results presented below are therefore discussed in terms of the data combined across the three age groups, hereafter referred to as Experiment 4, and compared to the results for the 3.0-year-olds only in Experiment 1.

Comparing performance across the three conditions yielded a highly similar pattern of results for the two experiments; compared to when both types of information were available (Control condition), performance was more affected by the removal of object information (Spatial condition) than by the absence of useful spatial information (Object condition) indicating that, at all ages, children relied more on the identity of the



objects than on their spatial position to find the analogous toy. One difference between the results for Experiments 1 and 4 is that, whereas at three years of age performance in the two experimental conditions (Object and Spatial) was not significantly different, children performed significantly better when only object information was available compared to when only spatial information was available for the data combined across three to five years of age. This shows that the ability to map individual objects, only somewhat more advanced in 3.0-year-olds continues to develop more rapidly than the ability to map spatial relations between a scale model and the referent space throughout the pre-school period (a pattern consistent with previous results, Blades & Cooke, 1994a; Bence & Presson, 1997).

Note that at all ages, the different levels of performance in the three conditions could not be attributed to difficulty encoding or remembering the different types of information (object, spatial or both), as children's memory for the original hiding location was always very good and surpassed their ability to find the analogous toy. Furthermore, the results could not be explained in terms of differences in the ability to learn the various strategies for solving the task as there was no evidence of improvement over trials at any age and in any condition.

#### Goal One: Sex and Children's Strategies

The results in Experiment 4 suggest that whereas girls continued to outperform boys when the task required mapping individual objects, boys advantage when a strictly spatial solution was required attenuated with age. Although the pattern of results for girls and boys observed in Experiment 1 was not identical to that observed in Experiment 4, the differences between the two sets of results appeared to be explainable in terms of the expected finding (based on previous results; see Blades & Cooke, 1994; Bence & Presson, 1997; DeLoache et al., 1995) that in all three conditions performance

generally improved with age. The important finding here, however, was that the pattern of improvement was different for boys and girls.

The results for girls in Experiment 4 was highly similar to those that obtained in Experiment 1; compared to when both types of information were available (Control condition), performance was relatively unaffected by disruption to spatial information (Object condition) but declined significantly when object information was no longer available to solve the task (Spatial condition). The group means for girls aged three to five years was 69%, 68% and 49% for the Control, Object and Spatial conditions respectively. The corresponding means for girls aged three years only were 60%, 60% and 33%. Thus, girls' performance in all three conditions improved with age. The only difference between the results for the 3.0-year-old girls in Experiment 1 and those that obtained for the 3.0- to 5.0-year old girls in Experiment 4 is that performance in the Spatial condition improved from being no different from chance in the former group to being significantly better than chance in the latter group. However, although the ability to interpret the model spatially improved with age, spatial information remained relatively unimportant to the way in which girls approached the task; provided object information was available, their performance remained unaffected by disruption to spatial information.

A further interesting finding for girls was that, in general, their performance did not vary with the type of hiding space (model or room). Indeed, the only effect of hiding space for girls occurred in the Control condition at three years of age (i.e. in Experiment 1). Recall that their performance was significantly above chance when the hiding event occurred in the room but not when it occurred in the model, possibly because standing beside the target container in the room may have underscored the type of information—object information—already salient to girls. That the effect did not obtain when the data for the three age groups were combined suggests that, with age, the effective use of the

object correspondence strategy was no longer dependent on the supportive context of witnessing the hiding event in the room. In the Control and Spatial conditions, girls' performance remained unaffected by the type of hiding space at all ages. The developmental pattern for girls' is therefore clear; the ability to map objects emerges earlier than the ability to map spatial relations, however, once acquired, the two abilities are sufficiently robust to be equally effective whether reasoning from the model to the room or vice versa. These findings raise the possibility that, for girls, the somewhat delayed development of the latter ability may be maturational.

A different developmental trajectory obtained for boys. Like girls, boys' ability to use the two types of information improved with age; the means for boys in the Control, Object and Spatial conditions (respectively) were 55%, 34% and 39% for the data from the 3.0-year-olds only and 65%, 50% and 47% for the data from the 3.0- to 5.0-year-olds combined. Unlike girls, however, the means in the two experimental conditions remained highly similar in the two experiments indicating that boys did not appear to favour a single strategy throughout the pre-school years. More striking, however, was the finding that boys' ability to capitalize on either strategy was highly dependent on the type of contextual support afforded by the nature of the hiding space.

Recall that in Experiment 1, boys performed best in the Control and Spatial conditions (the two conditions in which a spatial strategy would lead to task success) when the hiding event occurred in the model-- possibly because having an overview of the entire space may have helped them to place the target location within the spatial context. In contrast, their performance in the Object condition was uniformly poor for both hiding spaces. Combining the data across the three age groups revealed that the advantage of viewing the entire space during the hiding event in the Spatial condition persisted at four and five years of age (boys performance continued to be above chance

when the hiding event occurred in the model but not in the room). Interestingly, the reverse effect held in the Object condition where boys' performance also improved but only when they stood beside the target object when the hiding event occurred in the room (their performance was above chance when they observed the hiding event in the room but in the model). Boys' continued difficulty at using the object strategy when the hiding event occurred in the model could not be attributed to difficulty encoding or remembering the target location as their memory for the location of the original toy was very good, significantly surpassed their ability to find the analogous toy and did not vary with the nature of the hiding space. Furthermore, their inferior performance in the Object condition did not appear to result from the presence of misleading spatial information (arising from placing the objects in the model and the room in non-corresponding corners on the experimental trials) as only four 5.0-year-old boys erroneously searched in the corresponding corner, each on only one trial. Given the appropriate supportive context then, boys showed some ability to solve the task on the basis of either object or spatial information by the end of the pre-school years. That they were equally successful when both types of information were available in the Control condition, irrespective of the nature of the hiding space, is therefore unsurprising.

In sum, the above findings suggest that although both boys and girls showed some ability to solve the model task using either object or spatial information by the end of the pre-school years, whereas girls continued to rely predominantly on object information, boys strategies were subject to the availability of contextual support. While boys did not continue to show an advantage when the task had to be solved spatially, the different patterns of improvement that obtained for boys and girls in the three conditions suggest that the sex differences observed at three years of age may give rise to an

enduring sex difference (throughout the preschool years) in the way in which young children approach the scale model task.<sup>4.2</sup>

### Goal Two: The Role of Language

With respect to the hypothesis that girls' superior ability at mapping the individual objects between the experimental spaces might be accounted for by the tendency to apply linguistic labels to the target objects, the results were inconclusive. At least two possibilities for the results regarding the relation between vocabulary size and performance on the model task would have suggested that girls' tendency to focus on the objects might be subserved by the labeling strategy. The first possibility is that preschool girls may simply have significantly larger vocabularies than their male peers and thus be better equipped linguistically to generate and apply labels for the objects in the experimental spaces. This was clearly not the case in Experiments 1 and 4, however, as boys and girls vocabulary scores were comparable at all ages and did not vary either with condition or the nature of the hiding space.

The second possibility is that, even if girls and boys have similar lexical capacity, girls may be more likely than boys to co-opt their linguistic skills to solve the task at hand. By this view, vocabulary size would be expected to be positively correlated with girls' performance in the Control and Object conditions, the two conditions in which the object strategy would lead to task success. As boys were not thought to invoke the labeling strategy, no significant correlations would be expected at any age and in any condition. This second scenario for the relation between receptive vocabulary and performance on the model task also received very little support.

For boys, there were no significant correlations in the Spatial condition as expected. This finding is important for interpreting the results in the Control and Object

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<sup>4.2</sup> The broader implications of this difference are taken up in the General Discussion chapter at the end of this thesis.

conditions as it indicates that any significant correlations that might have obtained in those conditions would be unlikely merely to reflect the effects of general intellectual competence. There were also no significant correlations for boys in the Object condition (consistent with the idea that boys did not rely on labeling to solve the task), however, in the Control condition, contrary to expectations, a highly significant correlation obtained for boys at three years of age. Although for the most part language did not appear to be implicated in boys ability to solve any of the versions of model task, it is possible that for very young boys in the Control condition it provided an additional source of cognitive support. Perhaps boys began their search by looking to the corresponding spatial location, then used the label to verify that the object they encountered there matched the target object in the room. While this possibility is somewhat intriguing, caution is warranted in interpreting this isolated significant correlation for boys particularly as the sample in question is very limited ( $n = 6$ ).

The predictions suggested for girls by the second possibility outlined for the relation between language and performance on the model task received even less support. The correlations in the Spatial condition were not significant at any age (as expected), however, contrary to the predictions there were also no significant correlations for girls in the Object condition (at any age). One reason for this finding might be that the experimental manipulation (i.e. re-arranging the objects on every experimental trial) rendered object information sufficiently salient that the labeling strategy became unnecessary. Indeed, the only significant correlation for girls occurred for 5.0-year-olds in the Control condition perhaps suggesting that, with age, girls become attuned to the added benefit of labeling the target location. As with the results for boys, however, extreme care should be taken in interpreting this single significant correlation particularly given the very limited sample size ( $n = 8$ ). The sporadic significant correlations that emerged for boys and girls thus provided very little support



for the notion that while girls and boys may be similarly proficient in language, girls may be more prone than boys to using their language skills in problem-solving.

Perhaps the most important finding to obtain for the role of language in solving the model task was that the very limited and inconclusive pattern of results raises questions about the appropriateness of the linguistic measure employed. As a measure of receptive vocabulary the BPVS-II (Dunn et al., 1997) provides only a rough estimate of children's linguistic abilities, and importantly, cannot speak directly to individual differences in the tendency to use language as an aid to problem-solving. Furthermore, it is likely that the extent of children's vocabularies would have little bearing on whether or not they were capable of labeling the objects in the present experiment as even the youngest children are likely to have been adept at generating appropriate labels for the differently coloured hiding containers. The BPVS-II may thus have been ill-suited to tapping the linguistic capacity in question. Given the limited number of boys and girls in each of the conditions in Experiment 4 and concerns about the adequacy of the BPVS-II as an indicator of the use of the labeling strategy, the results for the relation between language and performance and mapping symbol-referent relations are best considered inconclusive. Further research is clearly needed to assess the possibility that children may bring their language skills to bear when using a spatial symbol to find a toy hidden in the referent space.

#### Goal Three: Implicit to Explicit Representations

The results from the analyses of successful children's responses to the knowledge question support the notion that young children's awareness of the model-room relation progresses from being implicit and unconscious to more explicit and conscious over the pre-school years (DeLoache & Marzolf, 1992). Whether or not successful children could articulate their knowledge of the parallel between the two spaces did not change significantly between three and four years of age, however, there



was a significant increase between four and five years of age. Thus, there are important advances around the fourth birthday years in conscious access to knowledge about the relation between symbol and referent.

The apparent advances between four and five years of age in successful children's ability to verbalize an understanding of the task could not be attributed simply to the greater maturity and confidence of the older children to interact with a strange, authority figure as 4.0- and 5.0-year-olds were equally likely to respond to the experimenter's question (incorrectly or correctly). Nor did the difficulty the younger successful children experienced in articulating their knowledge appear to be due to limitations in the size of their vocabularies. Although there were significant gains at four and five years of age in children's receptive vocabulary scores (as measured by the BPVS-II), the ability to verbalize the correct response remained significantly correlated with performance on the model task even after taking vocabulary into account.

Even when successful children were able to express verbally the relation between the scale model and the room, their responses were fairly limited. The large majority of successful children's correct responses tended to focus on the corresponding "behaviours" of the two toys with very few children (only five 5.0-year-olds) making specific reference to the strategy they employed to reason from the model to the room (i.e. whether they attended to the identity of the objects, to the spatial relations between the objects or both). In spite of similar levels of performance in the Control and Object conditions, more successful children articulated a correct response to the knowledge question in the former compared to the latter. However, as whether or not successful children responded correctly to the knowledge question did not vary significantly between either the Control and Spatial or the Object and Spatial conditions, it remains unclear whether the experimental manipulation in the Object condition yielded an advantage in conscious access to children's understanding of the task. Across

conditions, the ability to verbalize their understanding of the task did not vary for successful boys and girls. Relying on a more robust, less context-dependent strategy did not yield a more explicit representation of the task for girls.

Finally, it is interesting to note that at all ages there were a few children who, in spite of having a clear, verbalizable understanding of the model-room relation, nonetheless could not bring that knowledge to bear on their behaviour in the room. This group included boys and girls at all ages and in all conditions (but note that the relatively small samples precluded formal analyses of these data). These findings provided further support for previous claims that the developing ability to co-ordinate knowledge and action may play an important role in early symbolization (DeLoache, 2000; DeLoache et al., 1999; Solomon, 1997; 1999)

### Conclusions

In sum, the results in Experiment 4 reveal a sex-related difference in the extent to which young children rely on object and spatial information when using a scale model to navigate in the referent space that persists throughout the pre-school period. Whereas girls consistently rely primarily on the identity of the individual objects, the type of information to which boys attend is highly influenced by the task context. The results also reveal that children's representation of the model-room relation progresses from an implicit, non-verbalizable awareness at three years of age to a more explicit and verbalizable awareness by the age of five. Regarding the possibility that children may use language to assist in reasoning from the model to the room, the results from Experiment 4 are best regarded as inconclusive; a consequence of the combined effects of the insensitivity of the measure employed to assess the extent to which children rely on language in problem-solving and of the limitations of interpreting correlations drawn from very limited samples. Different methodology was therefore used in Experiment 5

in an effort to investigate the functional role of language in young children's understanding of scale models more directly.

## **Chapter 5**

### Experiment 5: Does Language Mediate Success on the Scale Model Task?

One of the main results in Experiment 4 was that, throughout the pre-school years, object information continues to predominate over spatial information in young children's strategies for using a scale model to navigate in the referent space. An important related result was that mapping the individual objects between the two spaces persisted as the strategy more strongly favoured by girls compared to boys. In Experiment 4 an initial gross attempt was made to explore one potential underlying cause for the observed reliance on the object strategy--the use of language. The idea was that perhaps children encode the identity of the target object linguistically (e.g. "the red one"), then use that linguistic representation to direct their search behaviour in the room. Of particular interest was whether or not the finding that girls were especially prone to using the object strategy could be related to the familiar claim that girls are precocious for language compared to boys (Maccoby & Jacklin, 1974). As an initial step in exploring this possibility, performance on the model task was correlated with a measure of receptive vocabulary (the BPVS-II; Dunn et al., 1997). This tack, however, yielded limited results. Small sample sizes and questions over whether a measure of lexical capacity might lack the sensitivity required to tap the relation (if any) between language and the ability to grasp the relation between a spatial symbol and the referent space suggest that the sporadic significant correlations arising in Experiment 4 are, at best, interpreted as inconclusive. True, the scant evidence in Experiment 4 may well indicate that language is not integral to solving the model task, however, previous theoretical and empirical work would suggest that the idea merits further, more rigorous, empirical investigation.

The notion that language may play a central role in cognition has a long history in developmental psychology. Most prominently, Vygotsky (1962), writing in the 1930's, regarded language as a developmental tool essential for the emergence of

higher cognitive processes. For Vygotsky, the acquisition of language afforded the direction of attention and thinking. Thus, language was thought to mediate mental processes such as attention, reasoning, problem-solving and the formulation of plans (Vygotsky, 1962). Over the years, a wealth of evidence from developmental studies in domains including theory of mind (e.g. Astington, 2001; Astington & Jenkins, 1999), memory (e.g. Vogel, 1979), judgements of perceptual similarity (Sloutsky & Lo, 1999), relational analogy (e.g. Gentner & Lowenstein, 1998, Gentner & Ratterman, 1998; Lowenstein & Gentner, 1998) and representational flexibility (Jacques & Zelazo, 2001), has accumulated to render this contention convincing. To date, evidence for the role of language in young children's ability to use symbolic representations *per se* has been largely lacking, however, recently, Callaghan (1999a; 1999b) has shown that, when required to select the object depicted in a picture from two perceptually-similar, three-dimensional choice objects, 2.5- and 3.0-year-old children performed better when they knew the labels for the target object compared to when they did not. Thus, there is some evidence that language may indeed have a role to play in children's ability to map the object depicted in a representation to the referent object itself. To be sure, the methodology employed and the accompanying theorizing on the nature of the functional role of language in cognition has varied across, and also within, domains. The main point here, however, is that the evidence converges to support the idea that language has an important role to play in scaffolding cognitive development in a number of domains including early symbolization.

More relevant to the present concern with sex differences and the role of language in using a spatial symbol, however, is the suggestion in the spatial reasoning literature that sex differences on spatial tasks appear to be explainable, at least in part, by a female advantage in language. For example, females, long thought to outperform males on measures of verbal IQ (e.g. Maccoby & Jacklin, 1974), and males who score

more highly on verbal than non-verbal/spatial measures, are more likely than controls to apply a verbal strategy to spatial reasoning tasks as diverse as mental rotation problems (Pezaris & Casey, 1991), the rod-and-frame test (Shore & Carey, 1984) as well as various sub-tests from standardized spatial reasoning batteries (e.g. Cochran & Wheatley, 1989). Thus, in lieu of taxing a relatively weaker spatial reasoning capacity, verbally competent individuals may interpret spatial tasks in terms of a comparatively better developed capacity for language.<sup>5.1</sup> The idea in the present research was to investigate the possibility that the female predisposition to approach spatial tasks linguistically may extend to using spatial symbols and that this tendency may take hold as early as in the pre-school years.

It is important to note that a shift in focus might occur when spatial tasks are represented linguistically. Whereas spatial strategies involve the global or holistic processing of stimuli, such as attending to distance and cardinal directions on a map or the relations between the items in a scale model, verbal strategies have the consequence of decomposing a spatial stimuli into their constituent elements such as landmarks and local directions or, in the case of scale models, the individual objects. At an age when children have mastered relatively few spatial relational terms (e.g. "left", "right" etc.) compared with descriptive word classes such as nouns and adjectives, a linguistic strategy would be even more likely to emphasize the components of a spatial array. Thus, it could be that for children who approach the model task verbally (i.e. girls, according to the present hypothesis) vocabulary limitations may constrain the type of information that can be encoded linguistically, hence the observed tendency to favour the object strategy.

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<sup>5.1</sup> Although boys and girls in Experiment 4 performed equally well on the BPVS-II (Dunn et al., 1997), as mentioned in the discussion of Experiment 4, preschool girls may simply be more prone to invoking their linguistic skills in problem-solving.



The primary aim in Experiment 5 was to address two main questions: 1). Do young children in general use language when mapping the elements of a scale model to their counterparts in the room the model stands for? and 2). Can the apparent predisposition of girls to rely primarily on the identity of the individual objects on the scale model task be explained by a greater tendency (compared to boys) to approach the model task linguistically? Accordingly in Experiment 5, methodological changes were introduced to the administration of the model task designed specifically to investigate the functional role of language directly. As the overarching goal of this thesis was to shed light on the nature of children's understanding of a spatial symbol when they first acquire the ability to use it (see the introduction), the target age group in Experiment 5 was three years of age.

#### Overview of Experiment 5

The overall design of Experiment 5 was highly similar to that of the experiments presented thus far in this thesis; the main difference was that, in addition to the availability of object and/or spatial information, the possibility of using the labeling strategy was also varied systematically. Identical boxes with pictures affixed to the front of each box were used as the hiding containers. Two sets of pictures were created that varied in their familiarity and thus the ease with which children could label them. The distinctiveness of the boxes, the possibility of labeling them according to the attached pictures and the availability of spatial information was achieved by varying the nature of the pictures on the boxes and the symmetry of the configuration of boxes in the experimental spaces.

Four conditions were created. In the Spatial condition, all of the boxes had identical pictures and the objects in the two spaces were arranged in the same way such that the task had to be solved spatially. In the Object-Easy condition, the individual boxes had different pictures of familiar objects, which children were expected to label

readily (hence *Object-Easy*), however, the configuration of objects in the model and the room was different such that children had to attend to the individual objects. Children could also label the objects (according to the pictures) to solve the task. However, as it was possible for children to succeed in the *Object-Easy* condition simply by perceptually discriminating the pictures on the boxes (i.e. without labeling them), an additional object condition was created. As in the *Object-Easy* condition, the objects in the two spaces occupied different locations in the model and the room, however in the *Object-Difficult* condition, instead of pictures of familiar items, the pictures on the boxes depicted unfamiliar abstract designs. As it was expected that children would find these more difficult to label (hence *Object-Difficult*), only the object correspondence strategy was available to solve the task. Performance in these conditions was compared to performance in a *Control* condition in which each box had a different, familiar (and thus easy to label) picture and the configuration of items in the model and the room was the same such that all three strategies—spatial, object and labeling—could be used to solve the task. The prediction was that if language is important for solving the model task, children should do well in the *Control* and *Object-Easy* conditions (familiar, easy-to-label pictures in both) and relatively poorly in the *Object-Difficult* (unfamiliar, difficult-to-label pictures) and *Spatial* (identical pictures, labels useless) conditions. If, however, perceptual discrimination of the individual objects was sufficient to explain the use of the object strategy, then they should do well in the *Control* condition as well as the two object conditions (object information available in all three conditions) and relatively poorly in the *Spatial* condition (no useful object information available).

A secondary aim in Experiment 5 was to explore the possibility that the ability to approach the task spatially might benefit from experience. Perhaps the four trials administered in the *Spatial* condition in Experiments 1 and 4 were insufficient for revealing the potential to learn to interpret the model spatially (recall that there was

no improvement over the two blocks of trials in the Spatial condition in Experiments 1 and 4). Accordingly, in Experiment 5, the number of trials children received was increased by administering the model task a second time, after a short delay. At the second time of testing, all of the children participated in the Spatial condition (identical boxes bearing identical pictures arranged in the same way in the model and the room). If increasing the number of trials would lead children eventually to catch on to the need to attend to the relations between the objects, then performance might be expected to improve from Time 1 to Time 2 for children who participated in the Spatial condition at both times of testing. Children were not expected to perform better in the Spatial condition at Time 2 after participating in either of the object conditions at Time 1, i.e. to be able to switch between the two strategies (object and spatial), however, the data would prove useful for establishing whether or not sheer familiarity with the task was sufficient to contribute to improved performance at Time 2. Finally, based on previous research indicating that performance on more challenging versions of the model task improves following experience with an easier version (DeLoache, 1991; Marzolf & DeLoache, 1994; Marzolf et al., 1996; Troseth & DeLoache; Uttal et al., 1995), it was expected that performance would be most likely to improve for children who participated in the Control condition at Time 1 followed by the Spatial condition at Time 2.

To ensure that children found the familiar pictures easier to label than the abstract designs, after completing the two versions of the model task, all of the children were presented with the pictures, individually and in random order, and asked to identify the item depicted. Their responses to the two sets of pictures were then compared. Finally, all of the children also received the receptive vocabulary measure used in Experiment 4 to investigate the reliability of the significant correlations between

vocabulary size and performance on the model task that emerged for 3.0-year-old boys and 5.0-year-old girls in the Control condition in Experiment 4.

## Method

### Participants

Sixty-four 3.0-year-olds ( $M = 40.2$  months, range = 36.2 - 43.8 months) with no previous experience with the model task participated in Experiment 1. Sixteen children (8 boys and 8 girls) were randomly assigned to each of four conditions: Control ( $M = 41.0$  months, range = 38.3 - 43.5 months); Object-Easy ( $M = 39.2$  months, range = 36.2 - 42.6 months), Object-Difficult ( $M = 40.6$  months, range = 36.9 - 43.8 months) and Spatial ( $M = 40.3$  months, range = 36.6 - 42.9 months). The nature of the hiding space (model or room) was counterbalanced as before but held constant across the two times of testing (see below).

### Apparatus and Materials

Scale Model Task. The model, room, hiding toys and the general experimental set-up were the same as those used in Experiments 1-4. The model had three walls and was open at the top and at the front (as in Experiment 2). The main difference between the apparatus used in Experiment 5 and that used in previous experiments was in the nature of the hiding containers. Whereas in Experiments 1-4 the containers were laminated paper bags sealed with velcro, the containers in Experiment 5 were four identical, red, corrugated cardboard boxes (large set: 30.5 x 21.8 x 24 cm, small set: 8.5 x 6.1 x 5.5cm) each with a flip-up lid and transparent plastic envelopes affixed to the front and top. The pictures that were inserted into the envelopes were black line drawings that occupied a rectangular area measuring approximately 14.8 x 15.6 cm and 3.7 x 3.5 cm for the large and small sets respectively. The drawings were printed on yellow paper and mounted on red card (large: 29.6 x 21.0 cm, small: 6.7 x 4.2 cm). Each box had two pictures; one placed in the transparent envelope on the front

of the box and an identical copy of the same picture placed in the transparent envelope on top of the box. This was done to ensure that children could see the pictures on the boxes whether they viewed them from the front (as when they entered the room) or from above (as when they stood in front the model). The orientation of the pictures on the boxes was kept constant across children and conditions.

Table 5.1 shows the three sets of four pictures that were used in Experiment 5. As only the pictures in the "Easy" and "Difficult" sets were used in the model task, they are described here. The third "Distractor" set of pictures is described below (see the section on the Picture Task). The labels "Easy" and "Difficult" refer to the relative ease of labeling the items within the two sets of pictures. The pictures in the Easy set (left column in the figure) depicted items familiar to young children including a sun, an umbrella, a jumper and a pair of scissors and the pictures in the Difficult set (middle column in the figure) depicted novel, abstract designs. Thus, it was expected that the items in the former would be more likely readily to prime linguistic labels than the items in the latter.<sup>5.2</sup> In order to achieve roughly equal discriminability amongst the items within each set of pictures, the Difficult items were constructed such that each Difficult picture corresponded (i.e. shared the most salient features; curves, angles, component shapes etc.) to one of the pictures in the Easy set (see Table 5.1). For ease of reference, the abstract pictures are therefore referred to as Abstract—Sun, Abstract—Umbrella, Abstract—Jumper and Abstract—Scissors.

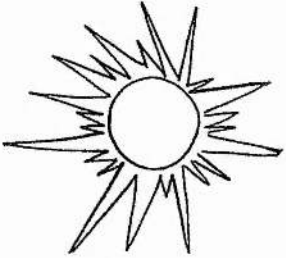
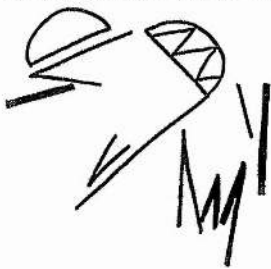
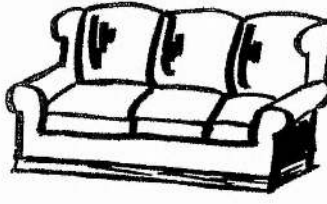

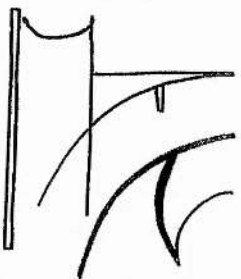

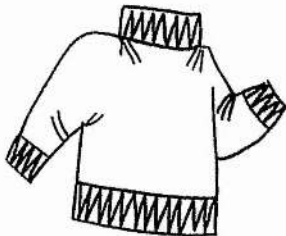
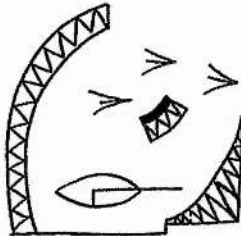
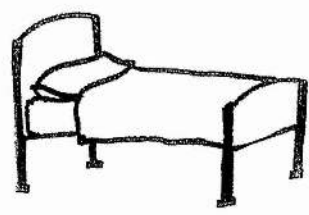
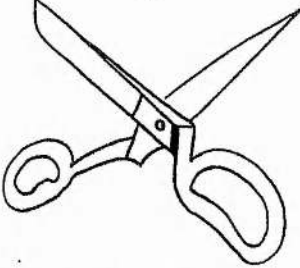
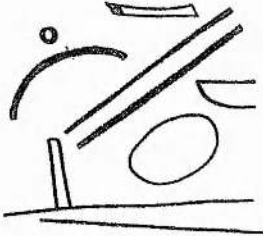
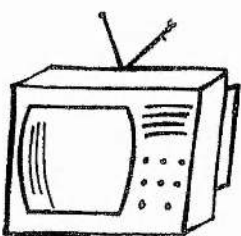
Four conditions that varied in the type of information available, and thus the strategies that could be used (object/spatial/labeling) to solve the task, were created by

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<sup>5.2</sup> The particular pictures shown were selected because extensive pilot testing with 3.0-year-old children who did not participate in Experiment 5 revealed reliable differences in the tendency to label the two types of pictures. Details of the pilot testing are not presented, however, as the responses of children who participated in Experiment 5 to the two sets of pictures were investigated formally in the Picture Task (see below). The relevant data are presented at the outset of the results section.

Table 5.1

The Three Sets of Pictures Used in Experiment 5

Easy (Easy to Label)	Difficult (Difficult to Label)	Distractor
		
"Sun"	Abstract--Sun	"Sofa"
		
"Umbrella"	Abstract--Umbrella	"Lamp"
		
"Jumper"	Abstract--Jumper	"Bed"
		
"Scissors"	Abstract--Scissors	"Television"

Children were expected to label the items in the Easy and Distractor columns either as shown or with appropriate synonyms such as "couch" for the sofa and "jersey" for the jumper. The labels in the Difficult column are included for reference purposes only. Only the Easy and Difficult Pictures were used for the scale model task. All three sets of pictures were used for the Picture Task.



varying the type of pictures displayed in the transparent envelopes on the boxes (Easy, Difficult or identical) and the symmetry of the configuration of boxes in the model and the room (same or different). The layout of the model and the room on the first experimental trial in each of the four conditions is shown in Figure 5.1. For ease of reference, the strategies available to solve the task in each condition are summarized in Table 5.2.

In the Control condition, each box had a different picture depicting a familiar object (one of the Easy pictures) and the boxes in the model occupied the same spatial position as their counterparts in the room. Thus, the object, spatial and labeling strategies could be used (either individually or in combination) to solve the task. The same pictures were used in the Object--Easy condition, however, on the experimental trials, corresponding boxes occupied non-corresponding spatial positions in the model and the room such that only the object and/or labeling strategies would lead to task success. The same manipulation was used in the Object-Difficult condition except that the Easy pictures were replaced with the Difficult, unfamiliar designs. As children were expected to find these relatively difficult to label, only the object strategy (i.e. without labeling) would lead to task success. And finally in the Spatial condition, all of the boxes had the same pictures such that the task had to be solved spatially. The pictures in the Spatial condition were sixteen copies (two on each of the four large and four small boxes) of one of the Easy pictures (sun, umbrella, jumper or scissors) with each picture being used equally often. Thus, four children who participated in the Spatial condition saw pictures of suns, four saw pictures of umbrellas, four saw jumpers and four saw scissors. Children who participated in the Spatial condition at both times of testing (see below) saw a different Easy picture the second time (e.g. suns at Time 1 and umbrellas at Time 2) with each picture used equally often as at the first time of testing.



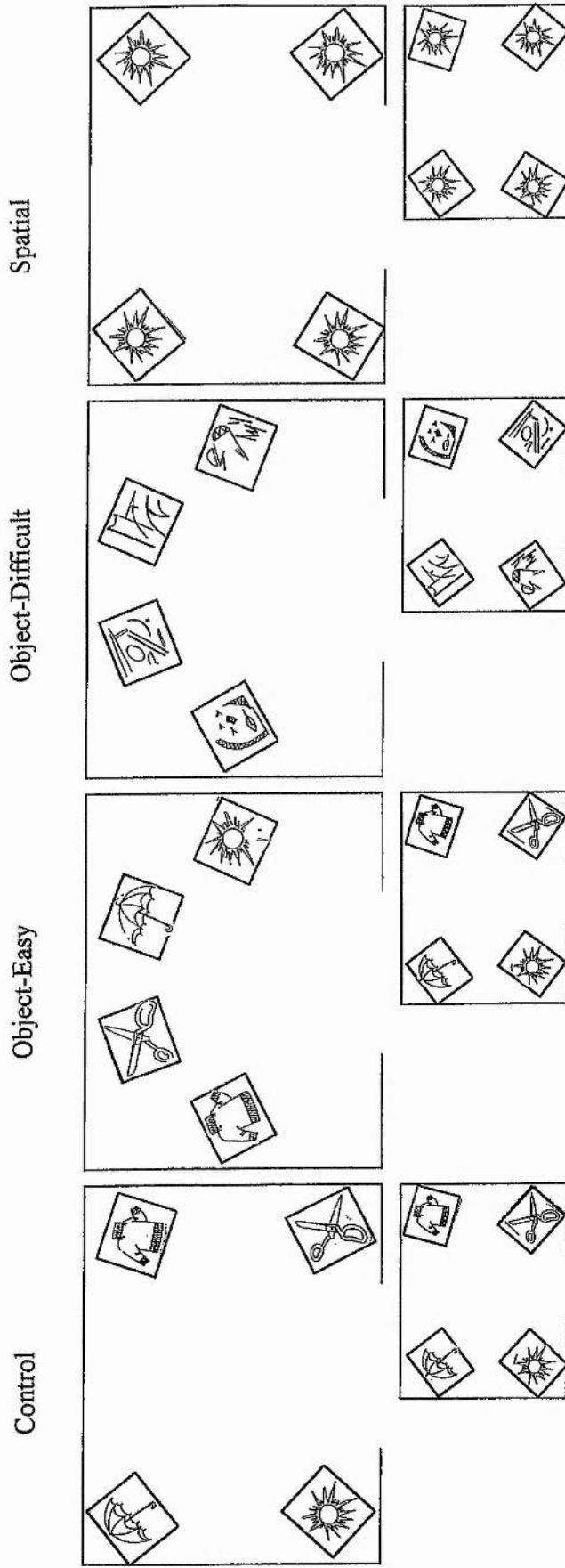


Figure 5.1 Layout of the Scale Model (small space) and the Room (large space) on the First Experimental Trial by Condition in Experiment 5. Black line drawings were affixed to the top (shown) and front of the four boxes. The boxes in the model were identical, except for size, to those in the room. In the *Control* condition, boxes with pictures of different, familiar objects (Easy set) occupied corresponding spatial positions in the model and the room; in the *Object-Easy* condition, boxes with pictures of different familiar objects (Easy set) occupied non-corresponding spatial positions in the two spaces; in the *Object-Difficult* condition, boxes with pictures of different, unfamiliar, abstract designs (Difficult set) occupied non-corresponding spatial positions and in the *Spatial* condition, all four boxes had the same pictures (one of the items in the Easy set).

Table 5.2

Summary of the Strategies Available to Solve the Scale Model Task in Experiment 5 by Condition.

Condition	Experimental Set-up	Possible Strategies
Control	pictures of different, familiar objects (Easy set) same spatial arrangement in model and room	object, spatial, labeling
Object-- Easy	pictures of different, familiar objects (Easy set) different spatial arrangement in model and room	object, labeling
Object-- Difficult	pictures of different, unfamiliar designs (Difficult set) different spatial arrangement in model and room	object
Spatial	pictures of identical objects same spatial arrangement in model and room	spatial

The strategies listed for the Control and Object-Easy conditions could be used alone or in combination.

Receptive Vocabulary Measure. The vocabulary measure was the BPVS-II (Dunn et al., 1997) used in Experiment 4 (see the Method section of Experiment 4 for a brief description and the accompanying manual for further details).

Picture Task. The Easy and Difficult pictures used in the scale model task, as well as the Distractor pictures (see the far right column in Table 5.1), were used for the Picture Task. The Distractor items were constructed in the same way as the large pictures in the Easy and Difficult sets (i.e. black line drawings, approximately the same size). For the Picture Task, however, all twelve pictures were printed on yellow A4 paper (21 x 29.7 cm) and inserted into clear plastic covers. Like the Easy set, the Distractor set also comprised pictures of objects familiar to young children. The items depicted included a sofa, a lamp, a bed and a television. These additional familiar items were included to help prevent children from becoming discouraged or bored by the challenge of generating labels for the Difficult pictures. That the four distractor items were all drawn from the same category—furniture—was not intentional; these pictures were selected as pilot testing with an earlier version of the experiment revealed that 3.0-year-old children could label them accurately and reliably.

### Procedure

Overview. All of the children received the same four tasks presented in the same order. The test session began with the administration of the version of the scale model task that corresponded to the condition to which children were randomly assigned i.e. Control, Object—Easy, Object—Difficult or Spatial (Scale Model Task--Time 1). Next, children were taken aside to a child-sized table and chairs where they received the vocabulary measure. Children were then taken back to the experimental set-up to participate in the Spatial version of the model task (Scale Model Task--Time 2), followed immediately by the Picture Task. The entire session lasted approximately 35-40 minutes.

Scale Model Task—Time 1. The procedure for the first administration of the scale model task was the same as that for Experiments 1 and 4 with the exception of five changes. Three of these changes were improvements to the procedure introduced in Experiments 2 and 3 (for details of these changes, see the Methods sections of Chapter 3). The remaining two changes were unique to Experiment 5. Only the five changes to the procedure will be described here; the reader is referred to the Methods section of Chapter 2 for a detailed description (and summary in Table 2.3) of the general procedure used in all the experiments in this thesis (i.e. unless otherwise stated).

The first change concerned the introduction of the hiding containers in the model at the start of the Familiarization Phase. Whereas in Experiment 1 the experimenter did not label any of the objects, in Experiment 5, she explicitly pointed out that the two pictures on the boxes were identical and, where possible, labeled the item depicted. Thus, in the Control and Object Easy conditions she said, "This box has a picture of (e.g.) a  *jumper*  on it here (pointing to the front), and here (pointing to the top of the box). Look, these two pictures are the same (indicating the top and front pictures)." She then continued, "This box has a different picture on it. It has a picture of an (e.g.)  *umbrella*  on it here, and here. Look, these two pictures are the same (indicating the two pictures)." and so on. In the Object—Difficult condition, she said, "This box has a picture  *like this*  on it here, and here" (pointing as before). Look, these two pictures are the same. This box has a different picture on it...". In the Spatial condition she said, "This box has a picture of (e.g.) a  *sun*  on it here, and here (pointing). Look they're the same (indicating the two pictures)." She then continued, "This box has the same pictures on it as the last one. Look, it has a picture of a sun here, and here." and so on. After introducing the fourth box, she said, "So all these boxes have different", (or "the same"), "...pictures on them ." (pointing to the four boxes). The procedure was repeated

for the boxes in the room. As in all the experiments reported in this thesis, the experimenter did not label the pictures on the boxes on the experimental trials.<sup>5.3</sup>

Changes two and three were the two changes to the procedure introduced in Experiment 2. Whereas in Experiments 1 and 4 children received up to four Placement Imitation trials, in Experiments 2 and 5, children received only one Placement Imitation trial and feedback and assistance in placing the analogous toy correctly was provided if their first placement was incorrect. In addition, the experimenter omitted the lengthy overviews of the task that preceded the Imitation Placement and Experimental trials in Experiments 1 and 4 and proceeded directly to place (for the Placement Imitation Phase) or hide (for the Experimental Phase) the original toy. These two changes were incorporated into the procedure of Experiment 5 to limit the overall length of the test session so that children would not become bored or inattentive before completing all four tasks. The results of Experiment 2 showed clearly that introducing these minor procedural changes had no effect on children's ability to find the analogous toy.

The fourth change, introduced in Experiment 3, concerned the configuration of items in the model and the room in the two object conditions. So that children would not be tempted erroneously to use the spatial strategy in either the Object—Easy or Object—Difficult conditions in Experiment 5, the configuration of the objects in the room was the same as that used in the Empty Corners condition in Experiment 3. Thus on the experimental trials, whereas one object was placed in each of the four corners of the model, the objects in the room were configured such that the corners of the room remained empty (one object was placed in the middle of each side wall and two objects were placed in the centre of the back wall, see Figure 5.1). The configuration of objects on the four trials (from left to right) was: 1). Jumper, Scissors, Umbrella, Sun; 2) Sun,

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<sup>5.3</sup> Labeling the hiding locations during the familiarization phase but not during the experimental phase is standard procedure in the DeLoache studies (e.g. DeLoache, 1991; DeLoache et al., 1991, Uttal et al., 1995 etc.).

Jumper, Scissors, Umbrella; 3). Umbrella, Sun, Jumper, Scissors and 4). Scissors, Umbrella, Sun, Jumper for the Object—Easy condition with the analogous arrangements used with the corresponding abstract designs in the Object—Difficult condition. In this way, the spatial positions of the objects in the model were irrelevant for successfully retrieving the analogous toy in the room and children had to rely on the object and/or labeling strategies (Object—Easy condition) or only the object strategy (Object—Difficult condition) to succeed.

The fifth and final change to the procedure was that, on each trial, immediately after children witnessed the hiding of the original toy, the experimenter pointed in the direction of the target container and said “Remember, LD (or BD) is hiding right there, now I’m going to hide BD (or LD) in the same place in BD’s room (or LD’s room) and then you can find him.”. So as not to over-emphasize the identity of the object over its spatial position, the experimenter took care never to touch the target object while pointing. This was done to encourage children to attend closely to the pictures on the boxes.

Vocabulary Measure. The BPVS-II (Dunn et al., 1997) was administered according to the standardized instructions summarized in the Methods section of Experiment 4.

Scale Model Task—Time 2. During the administration of the vocabulary measure, an assistant changed the pictures on the boxes in preparation for the upcoming Spatial version of the task. Testing at Time 2 began with the experimenter explicitly pointing out that the pictures on the boxes had changed. She then repeated the introduction of the individual boxes (in the model and also in the room) as carried out for the Spatial condition at Time 1. Next, she reminded children that the items in the model were the same as their counterparts in the room and demonstrated by holding up each miniature box from the model beside one of the large boxes in the room (this was



also done during the Familiarization Phase at Time 1 as part of the general procedure outlined in detail in Chapter 2). There was no Imitation Placement Trial at Time 2. After reminding children that the two ducks always do the same thing, the experimenter proceeded directly to administer four experimental trials (following the same procedure used at Time 1) using a different, randomly-selected hiding location on each trial.

Picture Task. The Easy, Difficult and Distractor pictures were used for the Picture Task such that all children saw twelve pictures. The Picture Task was administered at a child-sized table. The experimenter sat at a right angle and to the left of the child and kept the pictures face down in her lap during the instructions. She began by saying, "Let's play a picture game. I'm going to show you some pictures, one at a time, and all you have to do is tell me what's in the picture.". So that children did not feel compelled to provide labels for pictures they did not recognize, she then said, "I should warn you that some of my pictures are a bit odd-looking. Even I'm not sure what they are. So, if you don't know what's in the picture it's okay to say 'I don't know.'". She then asked children to repeat the phrase "I don't know" which they did without prompting. At the end of the instructions she reminded children, "Remember, if you do know what's in the picture you should tell me right away. But if you don't know what's in the picture, it's okay to say, 'I don't know'." The pictures were then presented individually, in random order. Each picture was placed upright on the table, in front of children, and the experimenter asked, "What's this?". If they did not answer the question within 10 seconds, the experimenter rephrased the question saying, "Can you tell me what's in the picture?". Immediately after children responded to the item depicted, the experimenter removed the picture, placed it face down on the table, out of children's reach, and introduced the next picture. The orientation of the Easy and Difficult pictures in the Picture Task was the same as in the scale model task with the orientation of all of the pictures kept constant across children.



Upon completion of the Picture Task, children were praised for their efforts and returned to their classroom. With the exception of the receptive vocabulary measure (which proved reliably easy to administer and score accurately in Experiment 4), the entire session was videotaped. Children's performance on the model task (at both test times) was scored live and checked against the videotapes for accuracy.

### Results

The data from one boy who participated in the Spatial condition at both test times was dropped from the analyses due to experimenter error (committed on the model task). The analyses are therefore based on the data from the remaining sixty-three children. As the central hypotheses in Experiment 5 were based on the assumption that children would label the Easy pictures more readily than the Difficult pictures, the results of the Picture task are presented first followed by the results for the Scale Model and Vocabulary Tasks.

#### Picture Task

The data from the Picture Task were analyzed in two ways: 1). in terms of the labels produced and 2). in terms of the reaction time to provide them. Both measures were taken from videotaped recordings of children's responses to the pictures.

As children could have been more likely, and quicker, to generate labels for the pictures they had seen during their participation in the scale model task (at Time 1 and also at Time 2), the ideal route to analyzing the data would have been to conduct the analyses for the "new" pictures (the ones to which children *were not* exposed during the model task) and the "old" pictures (the ones to which they *were* exposed) separately. Note, however, that as a consequence of the experimental manipulation, the total number of pictures to which children were exposed across the two times of administering the model task varied widely across the four conditions; children who participated in the Control and Object--Easy conditions saw the four Easy pictures at

Time 1 and one of the Easy pictures again at Time 2, children who participated in the Object-Difficult condition saw the four Difficult pictures at Time 1 and one of the Easy pictures at Time 2 and those who participated in the Spatial condition saw a different one of the Easy pictures at each time of testing. Likewise, the amount of time to which children were exposed to the various pictures also varied across conditions. For example, children who participated in the Control condition at Time 1 and the Spatial condition at Time 2 saw one of the Easy pictures at both times of testing but children who participated in the Object—Difficult condition only saw one of the Easy pictures and only at Time 2. Tabulating children's response to the "new" and "old" pictures separately therefore resulted in widely uneven sample sizes for the different pictures and picture sets. This, combined with the repeated measures design of the picture task, rendered statistical analysis of the "new" and "old" pictures separately untenable (too many missing data points to carry out the requisite paired comparisons).

To equate the number of responses across the three sets of pictures, and thus facilitate comparison of the relative percentage of correct responses across pictures and picture sets, the data were considered for all of the pictures (i.e. for the "old" and "new" pictures combined, hereafter referred to as the "old and new" pictures) and then compared to the data for the "new" pictures only. The results for both dependent measures (labels produced and reaction time) were highly similar for the two data sets. As the former, but not the latter, data set could be analyzed statistically, children's responses to the "old and new" pictures are presented in the figures and discussed in the text (see below) with the corresponding figures for the "new" pictures reported in parentheses for the purposes of comparison. The reaction time data are presented for both the "old and new" pictures and for the "new" pictures in the appropriate figure (see below) with inferential statistics reported for the former and the corresponding means reported in parentheses for the latter. As none of the children had seen the Distractor

pictures prior to the administration of the Picture Task (recall that the Distractor pictures were not used for the Scale Model task), the results for the Distractor pictures are reported only once along with the results for the “old and new” pictures (when the sample sizes were roughly equal for all three picture sets).

Picture Labels. Children’s verbal responses to the pictures were transcribed from the videotapes by two research assistants blind to the hypotheses of the study. Three children’s (two boys, one girl) responses to the Easy pictures, two children’s (both boys) responses to the Difficult pictures and seven children’s (six boys and one girl) responses to the Distractor pictures were not available due to technical difficulty leaving a total of sixty, sixty-one and fifty-six responses for each of the Easy, Difficult and Distractor pictures respectively.

The percentage of children who provided the various responses to the pictures are shown in Figure 5.2.1 for the Easy pictures, 5.2.2 for the Distractor pictures and 5.2.3a and 5.2.3b for the Difficult pictures. The white areas in the pie charts indicate the percentage of children who provided the expected responses i.e. they labeled the Easy and Distractor pictures correctly and said “I don’t know” to the Difficult pictures. Children’s responses to the Easy and Distractor pictures were scored conservatively and only the expected labels, along with a few close semantic approximations, were considered correct (see the legends accompanying Figures 5.2.1 and 5.2.2). Thus for example, the responses “top” and “jersey” but not “shirt” and “dress” were counted as correct responses for the jumper and “couch”, “settee”, “chairs” and “seat” but not “cushion” counted as correct responses for the sofa.<sup>5.4</sup>

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<sup>5.4</sup> To be sure, children could still succeed with the labeling strategy on the model task if they labeled a picture inaccurately, but consistently. However, as it was not possible to measure the consistency of children’s responses to the pictures during the model task, only labels that were a close semantic approximation the target response, perhaps more likely to be used consistently, were treated as correct.

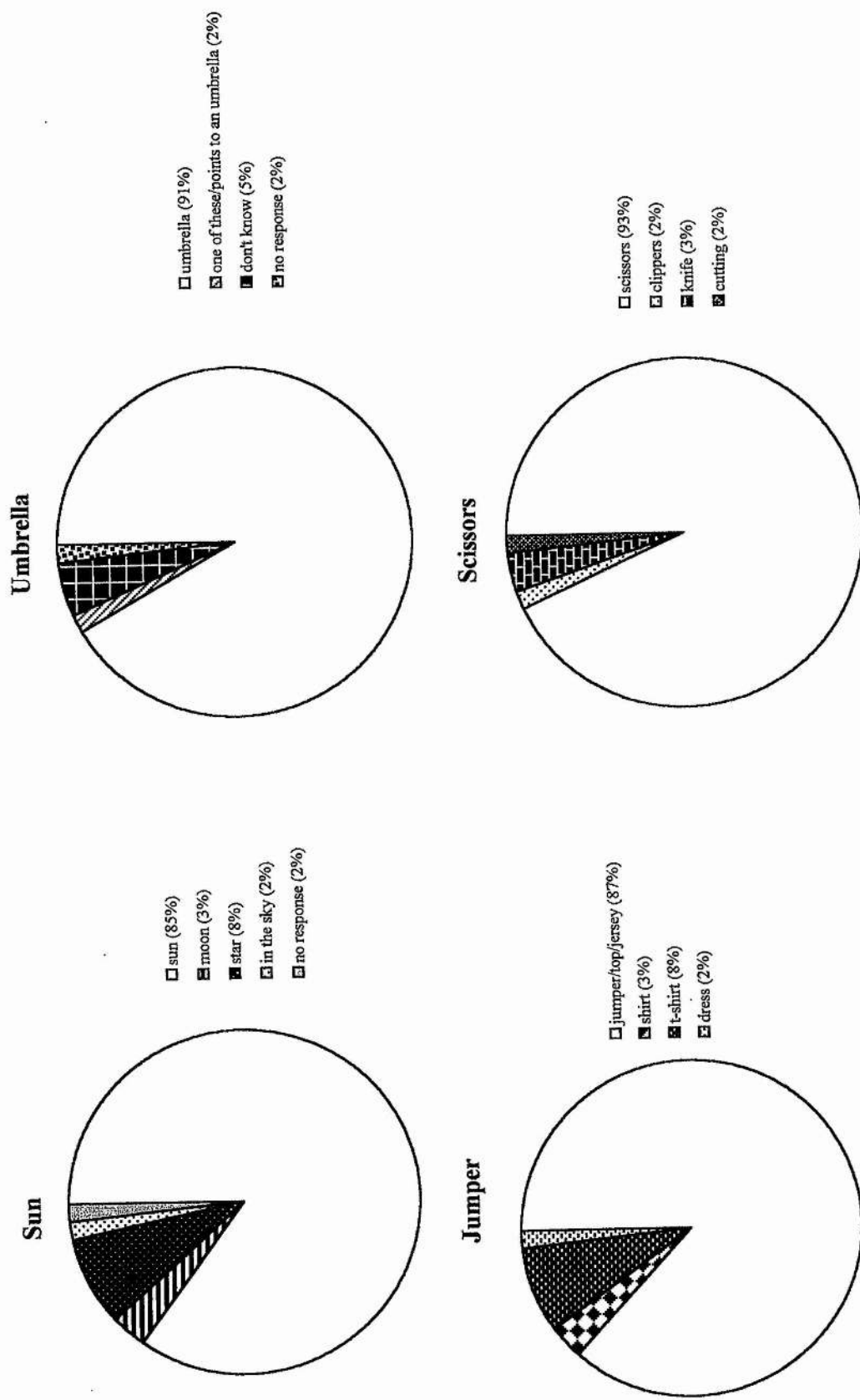


Figure 5.2.1 Children's responses to the Easy pictures (n = 60).

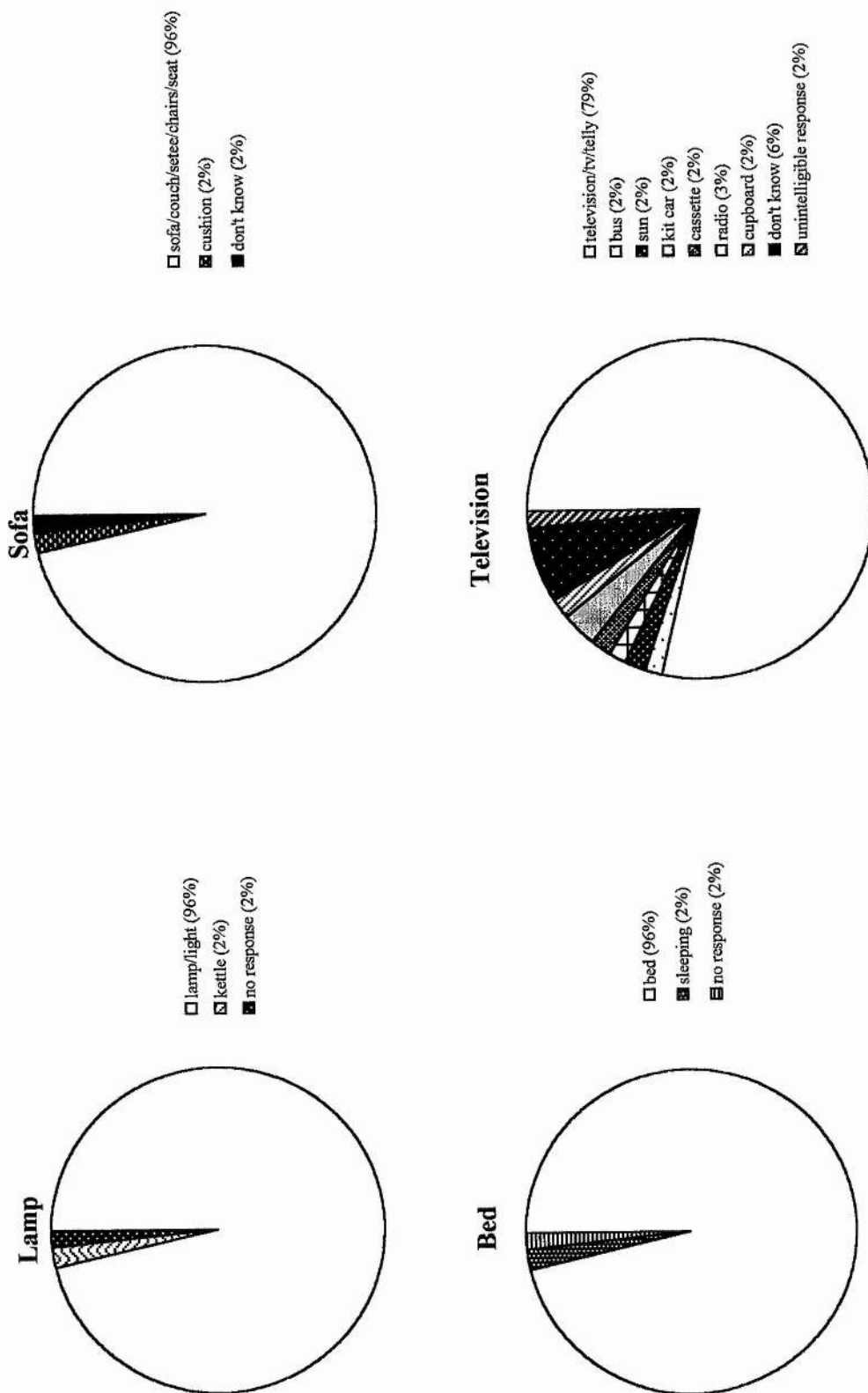


Figure 5.2.2 Children's responses to the Distractor Pictures (n = 56).

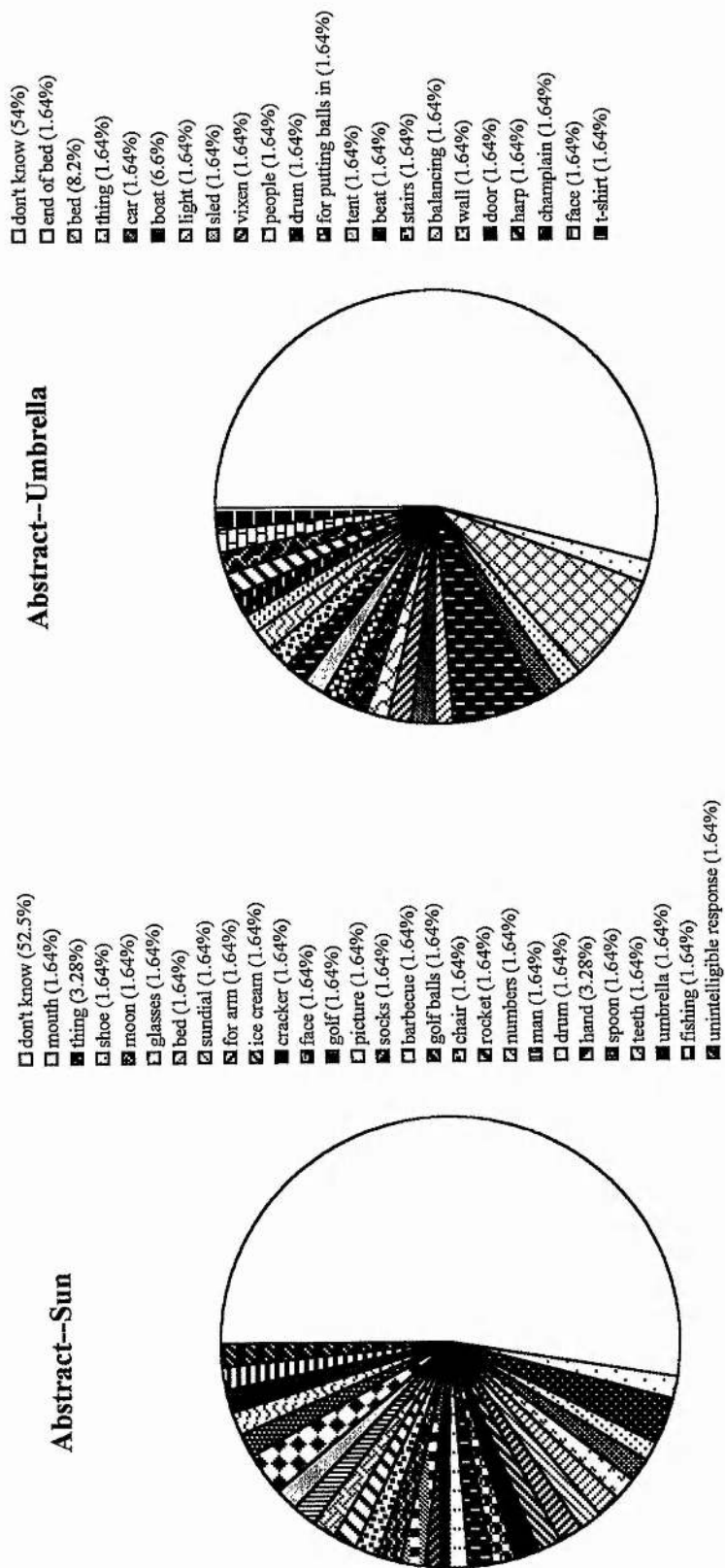


Figure 5.2.3a Children's responses to the Difficult pictures (n = 61); Abstract-- Sun and Abstract--Umbrella.

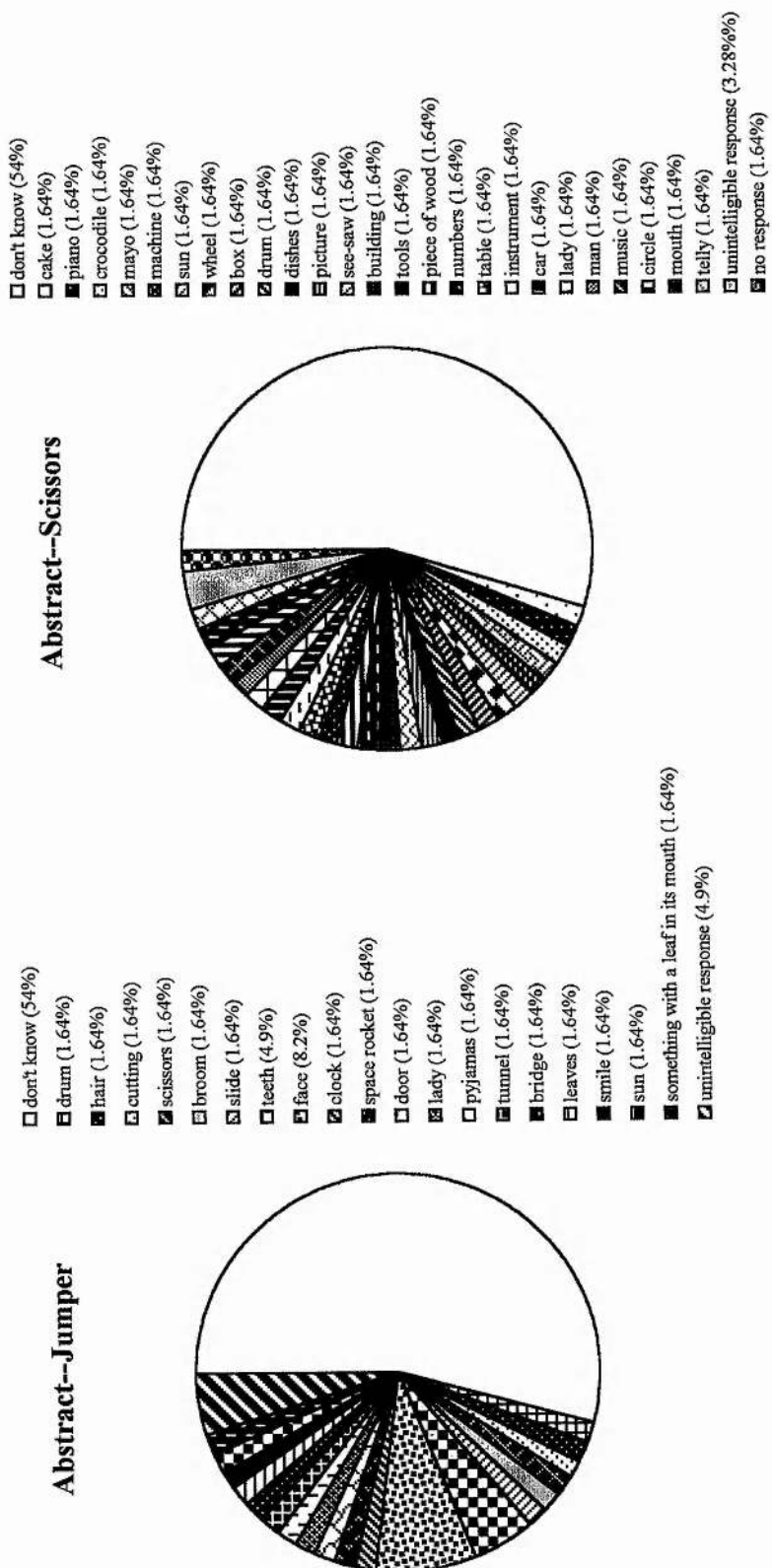


Figure 5.2.3b Children's responses to the Difficult pictures ( $n = 61$ ); Abstract--Jumper and Abstract--Scissors.



The results for the Easy and Distractor pictures, the two sets in which all of the pictures depicted objects familiar to children, were highly similar with the large majority of children providing an acceptable label for the item depicted (see Figures 5.2.1 and 5.2.2). The range for the Easy pictures was 85-93% (the corresponding figures for the “new” pictures were 71% for the sun, because five of the seventeen responses were “star”, and 88% for the remaining three easy pictures) and the range for the Distractor pictures was 79-96%.<sup>5.5</sup> Note that, in general, the alternative responses to the Easy and Distractor pictures were thematically related to the target item. For example, “moon” and “star” were provided in response to the picture of the sun and “clippers”, “knife” and “cutting” were provided in response to the picture of the scissors. Thus, most children recognized the item in the picture and only a very few children had difficulty retrieving an accurate label from memory. The important point here is that the large majority of children readily labeled the Easy and Distractor sets according to the item in the picture.

A very different pattern obtained for the Difficult pictures; only half of the sample responded correctly (in this case saying, “I don’t know”) with little variation across pictures. The percentages ranged from 52.5-54% (see Figures 5.2.3a and 5.2.3b, 47-51% for the “new” pictures). Furthermore, unlike the Easy and Distractor pictures, the alternative responses to the Difficult pictures varied widely. For example, the responses for the Abstract—Sun picture included “shoe”, “rocket” and “barbecue” and the responses for the Abstract—Scissors picture included “music”, “machine” and

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<sup>5.5</sup> The relatively low percentage of 79% correct occurred for the television. Four children (~7%) said “I don’t know” and an additional seven children (~14%) provided a range of different labels (see the legend for Figure 5.2.2) perhaps because the design used was somewhat outdated, and thus may have been unrecognizable to very young children. Ninety-six percent of children’s responses were correct for the remaining Distractor items (the sofa, lamp and bed).

“dishes”. Furthermore, there was very little consensus amongst the alternative labels (see the legends in Figures 5.2.3a and 5.2.3b). A maximum of five children (8% of the responses) provided the same response to a single alternative item (“face for the Abstract—Jumper picture and “bed” for the Abstract—Umbrella picture). The idiosyncratic labels and lack of consensus amongst children’s responses to the Difficult pictures suggests that, unlike the familiar pictures (the Easy and Distractor sets), the Difficult pictures did not readily prime a particular linguistic label.

To analyze the data statistically, the number of acceptable labels produced was tabulated for each of the three picture sets separately to yield three scores ranging between zero and four for each child. These scores were converted to percentages and group means were tabulated for each of the three picture sets. The resulting means for the Easy, Distractor and Difficult pictures were 89%, 93% and 51% (the corresponding means were 82% and 50% for the “new” Easy and Difficult pictures). Comparing the group means statistically confirmed the above interpretation of Figures 5.2.1-5.2.3; compared to the Difficult pictures, children were more successful at labeling the Easy,  $t(60) = 6.39$ ,  $p < .0001$ , and Distractor pictures,  $t(58) = 7.34$ ,  $p < .0001$ , with no difference between the two sets of familiar pictures (Easy and Distractor),  $t(57) = 1.04$ ,  $p > .30$  (related samples t-tests for all).

A further interesting finding is that children who provided the alternative labels for the unfamiliar, abstract designs appeared to do so for all of the Difficult pictures (with minor variation). Children were categorized as non-labelers if they said “I don’t know” to at least three of the four unfamiliar pictures, as “labelers” if they provided labels for at least three pictures and as “neutral” if they said “I don’t know” twice and labeled the remaining two pictures. Out of the 61 children for whom data were available, there were 31 non-labelers (51%, 12 boys and 19 girls), 28 labelers (46%, 15 boys and 13 girls) and only 2 neutral children (3%, both boys). For ease of analysis, the

two neutral children were randomly assigned, one to the “non-labeler” group and the other to the “labeler” group to yield 32 children (52%) in the former and 29 children (48%) in the latter. Children’s labeling status did not appear to be influenced by previous exposure to the unfamiliar designs during the model task as excluding the children in the Object—Difficult condition left 23 children (50%) in each of the “labeler” (13 boys and 10 girls) and “non-labeler” (9 boys and 14 girls) categories respectively. Boys and girls were equally likely to be classified as “labelers” or non-labelers”,  $p > .19$  for the analysis for all of the children ( $n = 61$ ) and also for the analysis excluding the children who participated in the Object—Difficult condition ( $n = 46$ , Fischer’s Exact). Thus, whether or not children had been exposed to the unfamiliar, abstract designs during the model task, they generally fell into two camps—those who tended to label the Difficult pictures and those who did not. The significance of this finding is taken up in the results reported for the model task below.

Reaction Time. A third research assistant, who did not transcribe children’s responses to the pictures and was blind to the hypotheses of the study, timed and recorded (to the nearest one hundredth of a second) the time elapsed between when children first saw the picture i.e. when it was placed on the table in front of them<sup>5,6</sup>, and the beginning of their response using a Timex stopwatch (no model or serial number shown on the instrument). The same research assistant timed all of the children’s responses.

Mean reaction times were tabulated for each of the three sets of pictures and are shown in Figure 5.3. The results are shown in the top plot for the “old and new” pictures and in the bottom plot for only the “new” pictures. The mean reaction times for the

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<sup>5,6</sup> A few impatient children attempted to see the upcoming picture while the experimenter was in the process of placing it on the table. In these cases, the assistant began recording the time to respond from the moment the picture was in sight. Children who did this were subsequently asked to remain seated throughout the picture task so that the remaining items could be placed on the table for clear viewing.

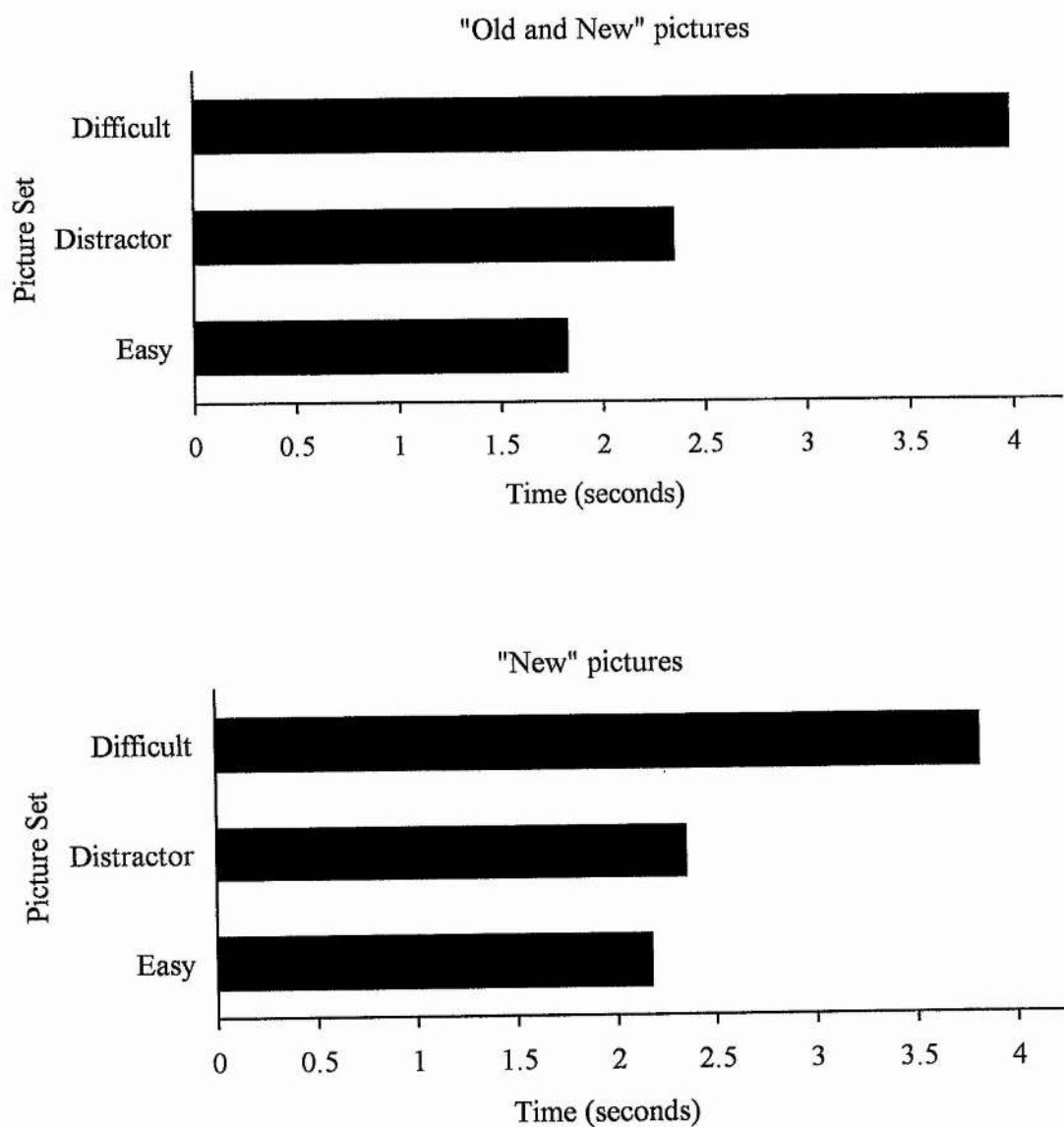


Figure 5.3 Reaction Time (in seconds) to Label the "Old and New" Pictures (top plot) and the "New" pictures only (bottom plot).

Easy, Distractor and Difficult pictures were 1.82, 2.35 and 3.98 seconds respectively for the “old and new” pictures (the corresponding times for the “new” pictures were 2.18 seconds for the Easy pictures and 3.82 seconds for the Difficult pictures). Thus, children took almost twice as long to produce a label for the unfamiliar, abstract designs compared to either of the two sets of pictures of familiar objects. Statistical analyses of the data for the “old and new” pictures revealed a significant effect of picture set,  $F(2, 102) = 26.45$ ,  $p < .0001$  (within subjects ANOVA); compared to the Difficult pictures, reaction time was significantly longer for both the Easy,  $t(54) = 6.04$ ,  $p < .0001$ , and Distractor,  $t(51) = 4.57$ ,  $p < .0001$ , pictures. Note that children were somewhat faster to respond to the Easy pictures (1.82 seconds) compared to the Distractor pictures (2.35 seconds),  $t(51) = 3.07$ ,  $p < .003$  indicating that previous exposure to pictures of familiar items during the model task conveyed a slight advantage (.53 seconds) in the time to produce labels for those items during the Picture Task (related-samples t-tests for all post hoc comparisons).

Comparing the top and bottom plots in Figure 5.3, it is clear that the pattern of results for the “new” pictures was highly similar to that for the “old and new” pictures. As for the “old and new” pictures, children took longer to respond to the Difficult pictures (3.82 seconds) compared to either the Distractor (2.35 seconds, as for the “old and new” data reported above) or Easy (2.18 seconds) pictures. Indeed, the only difference between the two plots was that there was very little difference in time to respond (0.17 seconds) to the Easy and Distractor pictures (i.e. when all of the familiar pictures were “new” to children). As mentioned above, the wide variation in the number of responses to the three sets of pictures (resulting from variation in the number of pictures to which children were exposed during the model task at the two times of testing) and a repeated measures design for the Picture Task, precluded inferential statistical analyses of the reaction time data for the “new” pictures only. It seems

reasonable to infer, however, that as the means for the two data sets were highly similar, the main finding for the “old and new” pictures, that children took almost twice as long to produce a label for the unfamiliar, abstract designs compared to either of the familiar sets of pictures, held whether or not children had previous exposure to some of the pictures.

In sum, both the results from the labels children produced for the items depicted as well as their reaction time to do so converge to suggest that children readily recognized and thus were more likely to label the Easy pictures compared to their Difficult counterparts. Furthermore, as children responded similarly to the Easy and Distractor pictures (in labeling and also in reaction time), but differently to the Difficult pictures, the difference between their responses to the Easy and Difficult pictures could not have been due to the specific set of familiar pictures included in the Easy set and instead appeared to reflect the effects of familiarity (and thus ease of labelability) more generally.

#### Scale Model Task

Time 1. The data for the Symbolic and Memory retrieval tasks were scored as in Experiments 1-4. The results by Task and Condition are shown in Figure 5.4. Across conditions, memory for the original hiding location was superior to the ability to retrieve the analogous toy, although memory performance in the experimental conditions was somewhat lower than in the Control condition. The means for the Control, Object-Easy, Object-Difficult and Spatial conditions (respectively) were 61% ( $SD = 25.77$ ), 38% ( $SD = 32.91$ ), 31% ( $SD = 28.14$ ) and 27% ( $SD = 22.09$ ) for the Symbolic Retrievals and 86% ( $SD = 20.35$ ), 73% ( $SD = 30.91$ ), 66% ( $SD = 32.76$ ) and 57% ( $SD = 26.16$ ) for the Memory Retrievals. In keeping with the Symbolic Retrieval results from Experiments 1 and 4, children performed best in the Control condition (61%) when all three types of information—object, spatial and linguistic—were

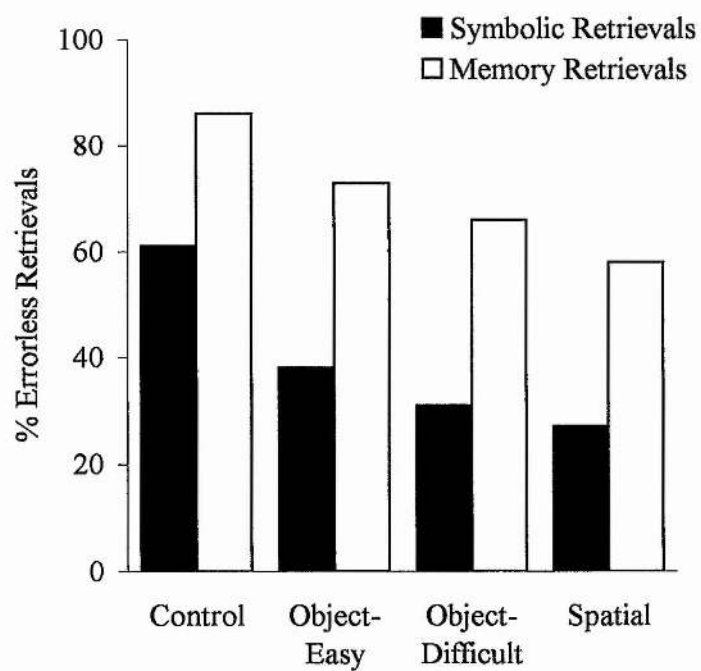


Figure 5.4 Results for the Scale Model Task at Time 1 in Experiment 5 By Task and Condition.



available and were most challenged in the Spatial condition (27%) when the task had to be solve spatially. In Experiment 5, however, mean performance in the two Object conditions, though between the means for the Control and Spatial conditions, was generally low, with little difference between the Object—Easy (38%) and Object—Difficult (31%) conditions.

The data were subject to a 2 (Task; symbolic retrieval, memory retrieval)  $\times$  4 (Condition; control, Object--Easy, Object—Difficult, Spatial)  $\times$  2 (Sex)  $\times$  2 (Hiding Space; model, room). The results revealed a main effect of Task,  $F(1, 47) = 44.1$ ,  $p < .0001$ , and a trend toward an effect of Hiding Space,  $F(1, 47) = 3.15$ ,  $p < .08$  which were subsumed by a Task by Hiding Space interaction also approaching significance,  $F(1, 47) = 3.69$ ,  $p < .06$ . As in previous experiments, children's memory for the original hiding location ( $M = 71\%$ ) surpassed their ability to retrieve the analogous toy ( $M = 39\%$ ). Performance on the Symbolic Retrieval task did not vary with the nature of the hiding space ( $M$ 's = 40% for the model and 39% for the room), however, memory for the original hiding location was significantly better when the hiding event occurred in the room ( $M = 80\%$ ), compared to the model ( $M = 62\%$ ). The ANOVA also revealed a main effect of Condition,  $F(3, 47) = 6.76$ ,  $p < .001$ ; compared to the Control condition, children performed significantly worse in the Spatial condition ( $p < .002$ ) but not in the Object—Easy condition ( $p > .13$ ). These results are similar to that in previous experiments (Blades & Cooke, 1994; Bence & Presson, 1997; DeLoache, 1990, Experiment 1; Marzolf et al., 1999, Experiment 1; see also Experiments 1-4 of this thesis) in suggesting that, provided the objects were visually distinct and could be labeled, the availability of object information continued to predominate over the availability of useful spatial information for young children's ability to use a scale model to find a hidden toy in the actual room.

Disentangling the roles of language and perceptual discriminability proved somewhat more complex. In addition to the absence of a significant difference between the Control and Object—Easy conditions and significantly poorer performance in the Spatial condition, the results also revealed significantly poorer performance in the Object-Difficult condition, ( $p < .02$  compared to the Control condition, Scheffé). This suggests that when spatial information was disrupted, benefits accrued to children for whom the pictures on the boxes could readily be encoded linguistically (i.e. in the Object—Easy condition). Note, however, that if this were true, then the difference between the means for the Object—Easy and Object—Difficult conditions (spatial information disrupted in both, pictures on the boxes more readily labeled in the former than in the latter) would also be expected to be significantly different—a finding that did not obtain, ( $p > .82$  for the comparison between the two object conditions, Scheffé).

One reason for these seemingly conflicting results might be that performance was generally poor in all of the experimental conditions. Although the difference between the means in the Control and Object—Easy conditions was not significantly different, as in Experiment 1, performance in the Object—Easy condition (38%) in Experiment 5 was somewhat poorer than in the comparable Object condition in Experiment 1 (47%, in which the hiding containers were also perceptually similar and could have been labeled e.g. according to their colour). Not only were none of the differences between the group means in the experimental conditions significantly different (Object—Easy vs. Object—Difficult,  $p > .82$ ; Object—Easy vs. Spatial,  $p > .40$ ; Object—Difficult vs. Spatial,  $p > .89$ ; all tests Scheffé), but comparing the group means to chance (25% for choosing the correct one of four hiding locations) revealed that performance was above chance in the Control condition,  $t(15) = 5.58$ ,  $p < .0001$ , but not any of the experimental conditions (Object—Easy,  $t(15) = 1.52$ ,  $p > .15$ ; Object—Difficult,  $t(15) = .89$ ,  $p > .39$ ; Spatial,  $t(14) = .29$ ,  $p > .77$ , one-sample tests). The

failure to find a significant difference between the two object conditions may thus be a consequence of a floor effect occurring in the experimental conditions.

Note, however, that scrutinizing the data more carefully revealed that another reason why a difference between the means in the two object conditions failed to obtain may be that there were individual differences in the tendency to encode the target object linguistically. Recall that it was possible to classify children as "labelers" or "non-labelers" according to whether or not they labeled at least three of the four Difficult pictures on the Picture Task. The result was roughly equal numbers of children in each of the "labeler" and "non-labeler" groups (twenty-nine in the former and thirty-two in the latter, each comprising roughly equal numbers of boys and girls).

To explore the possibility that the predisposition to generate labels even for the unfamiliar pictures might prove advantageous on the model task the data were analyzed for the two groups separately. Figure 5.5 shows the Symbolic Retrieval results at Time 1 for the "Labeler" and "Non-Labeler" groups. A 4 (Condition; control, object—easy, object—difficult, spatial)  $\times$  2 (label status; "labelers", "non-labelers") ANOVA revealed a main effect of Condition,  $F(3, 53) = 5.13$ ,  $p < .003$ , consistent with the pattern that obtained in the original mixed ANOVA reported above, as well as a trend towards a Label Status by Condition interaction,  $F(3, 53) = 2.43$ ,  $p < .08$ . Subsequent analyses revealed that children who tended to encode the pictures linguistically significantly outperformed their non-labeling peers in the Object—Easy condition ( $M = 50\%$  vs.  $18\%$ ,  $t(13) = 2.15$ ,  $p < .05$ ) but not in any of the other conditions ( $M = 57\%$  vs.  $64\%$ ,  $t(14) = -.51$ ,  $p > .62$  for the Control condition;  $M = 21\%$  vs.  $39\%$ ,  $t(13) = -1.20$ ,  $p > .25$  for the Object—Difficult condition and  $M = 25\%$  vs.  $29\%$ ,  $t(13) = -.30$ ,  $p > .77$  for the Spatial condition). That the Label Status by Condition interaction did not quite reach significance is likely a reflection of the limited power of the ANOVA, a consequence of the fairly limited number of observations in each of the subgroups ( $n$ 's ranging from six

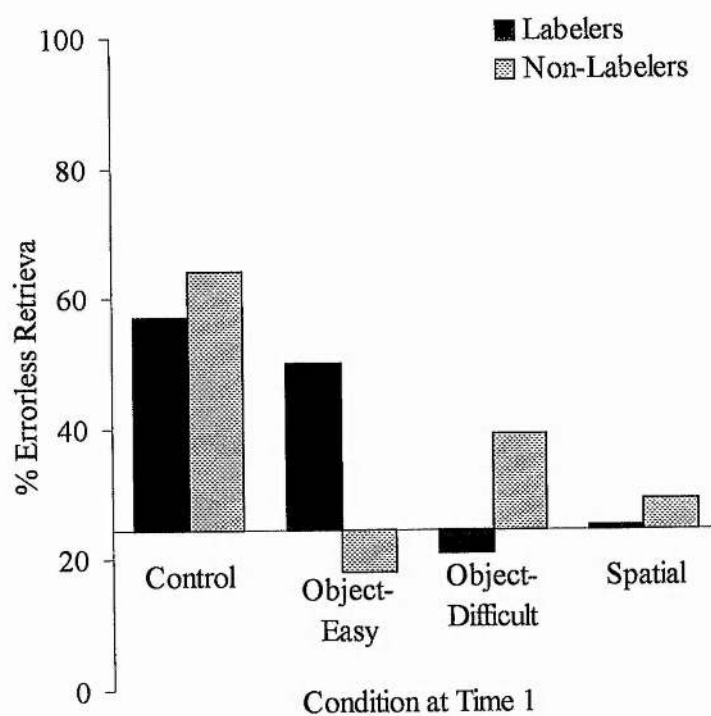


Figure 5.5 Symbolic Retrieval Results at Time 1 for the "Labeler" and "Non-Labeler" Groups. The axes in the figure intersect at chance (25%).

to nine children). Nonetheless, the data provide some indication that when only object information was available to solve the model task, for some children, the possibility of encoding the target object linguistically proved beneficial to task success. The apparent floor effect that obtained in the Object—Easy condition thus appears to be due to only half of the children capitalizing on the availability of the linguistic strategy.

There were no other significant effects in the initial mixed ANOVA reported at the outset of the results for the model task at Time 1. Thus, in contrast to previous experiments, there was no indication in Experiment 5 that boys and girls approached the model task differently at the first time of testing.

Finally, mean performance for each of the two blocks of trials (i.e. the mean of trials 1 and 2 and the mean of trials 3 and 4) at Time 1 was tabulated as in previous experiments and the data were subjected to a 2 (Trial Blocks; block 1, block 2)  $\times$  4 (Condition; control, object—easy, object—difficult, spatial) ANOVA. The results revealed no effect of Trial Blocks and no interaction with the Trial Blocks variable. As in Experiments 1-4, there was no evidence of performance across trials.

Time 2. Figure 5.6 shows the results for Time 2, when all of the children participated in the Spatial condition, by Task and Condition at Time 1. The means at Time 2 for children who had first participated in the Control, Object-Easy, Object-Difficult and Spatial conditions at Time 1 (respectively) were 38% (SD = 32.91), 30% (SD = 16.38), 34% (SD = 22.13) and 22% (SD = 12.68) for the Symbolic Retrievals and 56% (SD = 28.14), 53% (SD = 22.13), 64% (SD = 31.58) and 38% (SD = 31.15) for the Memory Retrievals. As is apparent in the figure, the notion that previous experience with the model task might lead to an improved ability to approach the task spatially was not supported. The Symbolic Retrieval means for children who participated in the Spatial condition at both times of testing were highly similar (M = 27% at Time 1 and

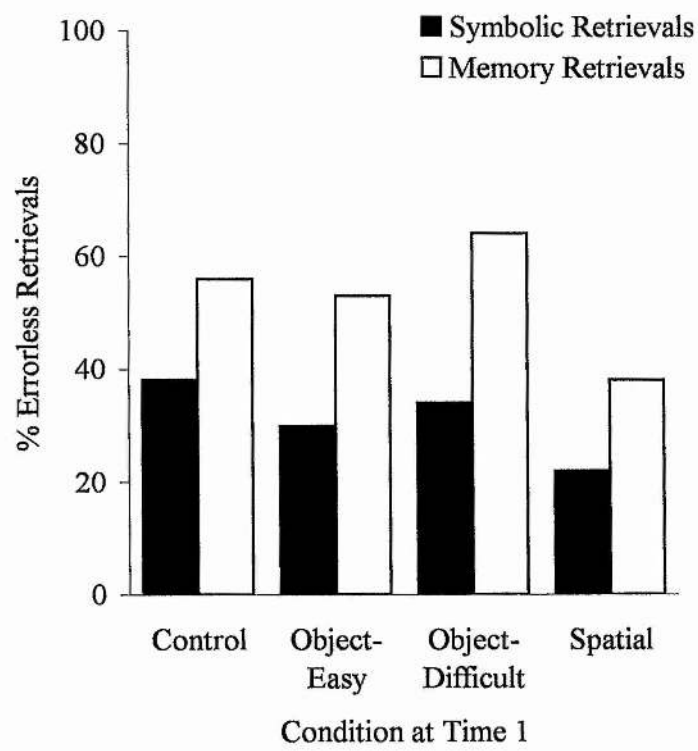


Figure 5.6 Results for the Scale Model Task at Time 2 in Experiment 5 (all children participated in the Spatial condition) by Task and Condition at Time 1.

22% at Time 2,  $t(14) = .66$ ,  $p > .52$  (paired-samples) indicating that extending the number of experimental trials did not lead children to catch on to the need to attend to the spatial relations between the individual objects. There were also no significant differences when Symbolic Retrieval performance at Time 2 (spatial version of the task), for children who first participated in the Control, Object—Easy and Object—Difficult conditions at Time 1, was compared to performance in the Spatial condition at Time 1 ( $t(29) = 1.07$ ,  $p > .29$  for the Control group,  $M$  at Time 2 = 38%;  $t(29) = .43$ ,  $p > .67$  for the Object—Easy group,  $M$  at Time 2 = 30%, and  $t(29) = .97$ ,  $p > .34$  for the Object—Difficult group,  $M$  at Time 2 = 34%, independent samples  $t$ -tests for all. Thus, performance in the Spatial condition at Time 2 did not appear to benefit either from previous experience with an easier version of the task (participating in the Control condition at Time 1) or from experience with the task procedures in general (participating in either of the object conditions at Time 1).

Note, however, that the absence of significant effects in the above analyses could be due to floor effects on the Symbolic Retrievals occurring for all four groups at Time 2. Comparing the group means to chance (25%) revealed that for the Symbolic Retrieval task none of the means were significantly above chance: Control,  $t(15) = 1.52$ ,  $p > .15$ ; Object—Easy,  $t(15) = 1.15$ ,  $p > .27$ ; Object—Difficult,  $t(15) = 1.70$ ,  $p > .11$ ; Spatial,  $t(14) = -.98$ ,  $p > .35$ . Indeed, memory for the original hiding location, a task at which children typically excel, also appeared to suffer at Time 2. Although the means for the Memory Retrievals at Time 2 were significantly above chance for all children except those who participated in the Spatial condition at both times of testing (Control,  $t(15) = 4.44$ ,  $p < .0001$ ; Object—Easy,  $t(15) = 5.08$ ,  $p < .0001$ ; Object—Difficult,  $t(15) = 4.95$ ,  $p < .0001$ ; Spatial  $t(14) = 1.66$ ,  $p > .12$ ), a 2 (Memory Retrievals: time 1, time 2)  $\times$  4 (Condition at Time 1: control, object—easy, object-difficult, spatial)



mixed ANOVA revealed that, across conditions, Memory Retrieval performance was significantly worse at Time 2 compared to Time 1,  $F(1, 59) = 16.09, p < .0001$ .<sup>5.7</sup>

The generally depressed mean scores at Time 2 raise questions as to whether children simply lacked the cognitive resources, perhaps due to fatigue or boredom, at the end of the test session adequately to assess the possibility of improvement on the spatial version of the task across the two times of testing.

As at Time 1, to determine if there was any change in performance over the two blocks of trials, the data were analyzed by a 2 (Trial Blocks; block 1, block 2)  $\times$  4 (Condition; control, object—easy, object—difficult, spatial) ANOVA. There were no significant effects in the ANOVA and thus no evidence of improved performance over trials at Time 2.

#### Receptive Vocabulary Task

The BPVS-II was scored according to the guidelines in the accompanying scoring manual (Dunn et al., 1997) to yield raw scores or the total number of words children understood. Mean vocabulary scores were then tabulated for each condition and the results were subjected to a 4 (Condition; control, object—easy, object—difficult, spatial)  $\times$  2 (Sex)  $\times$  2 (Hiding Space; model, room) ANOVA. That the results revealed no significant effects indicates that all of the children who participated in Experiment 5 were equated in the extent of their vocabularies.

As in Experiment 4, children's receptive vocabulary scores were correlated with performance on the Symbolic Retrieval task for boys and girls in each of the four conditions separately. The results, presented in Table 5.3, show clearly that there were no significant effects for either boys or girls in any condition. The finding in

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<sup>5.7</sup> The only other significant effect in the ANOVA was a main effect of Condition,  $F(3, 59) = 2.95, p < .04$ . At both times of testing, Memory Retrieval performance was superior in the Control condition compared to the Spatial condition ( $p < .05$ , all other comparisons were non-significant,  $p$ 's  $> .24$ , Scheffé).

Table 5.3

Performance Correlations Between Receptive Vocabulary Raw Scores and Symbolic  
Retrieval by Condition and Sex

	Condition			
	Control	Object-Easy	Object-Difficult	Spatial
<u>Sex</u>				
Girls	+0.15 n = 8	+0.04 n = 8	+0.09 n = 8	-0.10 n = 8
Boys	+0.42 n = 8	+0.62 n = 8	+0.50 n = 8	+0.32 n = 7

All of the correlations (Spearman's rho) were non-significant.

Experiment 4 that at three years of age lexical capacity was correlated with Symbolic Retrieval performance for boys in the Control condition thus did not obtain in Experiment 5. To assess the sensitivity of the vocabulary measure for tapping the tendency to encode object information (i.e. the pictures) linguistically, children's receptive vocabulary scores were also correlated with their label status assigned on the basis of their tendency to generate labels even for the unfamiliar, Difficult pictures (see the results for the Picture Task). The result was clear—even with the substantial sample of sixty-one children, the correlation was not significant,  $r = -.15$ ,  $p > .25$  (Pearson). Analyzing the data for boys and girls separately yielded the same non-significant result ( $r = -.12$ ,  $p > .53$ ,  $n = 29$  for boys and  $r = -.17$ ,  $p > .35$ ,  $n = 32$  for girls). The extent of children's vocabularies thus proved a poor indicator of the tendency to invoke their linguistic skills to solve the task at hand.

## Discussion

### Picture Task

The results from the Picture Task provide strong support for the a priori notion that children would find the pictures of familiar objects easier to label than their abstract, unfamiliar counterparts. A very high percentage of children accurately labeled the Easy (85-93%) and Distractor pictures (79-96%), taking almost half the time it took to label the Difficult pictures (1.82 and 2.35 seconds for the Easy and Distractor pictures vs. 3.98 for the Difficult pictures). The very few children who were unable to produce accurate labels for the familiar pictures nonetheless appeared to recognize the object depicted producing labels that were thematically related to the target item such as calling the scissors "knife" or "cutting". This suggests that their responses were driven by the item itself. In marked contrast, only half of the children (52.5-54%) labeled the Difficult pictures. Moreover, the labels generated varied widely, were highly idiosyncratic (i.e. they did not appear to be thematically related) and there was little

consensus amongst children for the labels produced (a maximum of only five children providing the same label for a given item). Unlike the Easy pictures, children's responses to the Difficult pictures suggest that the unfamiliar, abstract designs did not readily prime a particular linguistic label.

To be sure, it is possible that children could still succeed with the labeling strategy on the model task even if they used either an inaccurate label for the familiar pictures or an idiosyncratic label for the Difficult pictures (as half of them did on the Picture Task) provided they used these labels consistently. This latter possibility seems particularly unlikely, however, as children did not produce labels for the unfamiliar designs automatically, on demand, taking substantially longer to label them compared to their Easy counterparts. Furthermore, the association between an ad hoc label and a given picture might be expected to be more difficult to remember and thus would be less likely to be used consistently and effectively. Even so, the difference in the feasibility of using the labeling strategy in the Object--Easy and Object--Difficult conditions would still be substantial as only half of the children (at most) who saw the Difficult pictures, but almost all of the children who saw the Easy pictures, would have benefited from labeling the pictures on the target containers. The predicted differences between performance in the two object conditions would therefore still obtain if labeling the target objects was important for task success.

It is worth noting that the pattern of results for the labels produced and also for the reaction time data held both when considering the responses to all of the pictures (the "old and new" pictures) and also when only the responses to pictures to which children were not exposed during the model task (the "new" pictures) were taken into account. The means for the two sets of data were highly similar, the only difference being that the data from the "old and new" pictures, showed that children gained a slight advantage in the time to label familiar items on the Picture Task if they had already seen

them during the model task. Children were half a second faster at labeling the Easy pictures (previously seen by at least half of the children) compared to the Distractor pictures (new to all of the children) perhaps providing a hint that they had generated labels for the Easy items during the administration of the model task. The important finding, however, is that even with this slight advantage, children still took significantly longer to label the Difficult pictures compared to both the Easy and Distractor ones.

Note as well that as children responded similarly to the Easy and Distractor pictures but differently to the Difficult ones, the observed labeling and reaction time differences between the Easy and Difficult pictures (the picture sets used on the model task) could not be attributed to the particular items depicted in the Easy set. Instead, differences in the familiarity of the items depicted in the pictures appeared to result in clear differences in the ease with which those items could be labeled. As the nature of the pictures on the boxes was the only difference between the two object conditions, any differences arising between the means in the two conditions could therefore be taken to reflect the effects of the relative ease of using language to solve the task. The important point here is that the Picture Task data indicate that the manipulation of varying the nature of the pictures on the boxes in the two object conditions was effective for disentangling the roles of perceptual discriminability and the use of language in reasoning from the model to the room.

### Scale Model Task

At the group level, the results for the model task at Time 1 were in keeping with those of the studies reported so far in this thesis; children performed best when both object and spatial information were available (Control condition), were relatively unaffected by the removal of useful spatial information (Object—Easy condition) and were most challenged when only spatial information was available to solve the task (Spatial condition), once again suggesting that the identity of the individual hiding

locations was of primary importance to children when using a scale model to find a hidden toy in the actual room.

The notion that, at three years of age, children may approach the model task by labeling the target item in the model and using that label to guide their search in the room received support from two types of analyses. The first type of analysis was based on the group means in the four conditions. Children performed well in the Control and Object—Easy conditions, the two conditions in which the pictures on the containers were familiar to children and for which they knew the labels. In contrast, when spatial information was disrupted and labeling the pictures on the target container was made more difficult (Object—Difficult condition), or the labeling strategy became unfeasible (as in the Spatial condition when the pictures on the containers were identical), they performed significantly worse. This suggests that the relative ease of labeling the target containers played a role in mapping the target item in the model to its counterpart in the room. The second type of analysis was suggested by an intriguing finding that arose in the analyses of the Picture Task data. Recall that children could be categorized into two groups -- those who tended to label all of the pictures (even the unfamiliar, Difficult ones) and those who labeled the familiar pictures and said they did not know what was depicted in the unfamiliar ones. Taking this finding as an indication that half of the children were inclined to represent the picture on the target container linguistically, the data were then analyzed for the "labelers" and "non-labelers" separately. The intriguing finding was that the children identified as "labelers" were significantly more successful than their "non-labeler" peers in the Object—Easy condition, but not in the Object—Difficult condition (both groups performed well in the Control condition and poorly in the Spatial condition). Thus, where the target object could be labeled relatively easily, benefits accrued to those children who appeared to approach the model task



linguistically. These findings indicate that language may indeed contribute to task success.

It is noteworthy that the difference between the group means in the Object—Easy and Object—Difficult conditions did not reach significance. As the only difference between the two conditions was in the ease of labeling the target pictures, one might expect that, if (as the above analyses suggest) children did indeed use the labeling strategy, then performance in the Object—Easy condition should have been superior to performance in the Object—Difficult condition. Further scrutiny of the model task data suggests that there are at least two reasons for the seeming contradiction between the absence of this finding and the above results suggesting the use of the labeling strategy. One reason, of course, is that a difference between the means in the two object conditions was likely to be obscured by the fact that only half of the children appeared to represent the pictures linguistically. As the analyses of the group means were carried out on the data for the “labelers” and “non-labelers” combined, it is perhaps unsurprising that the difference between the means in the two object conditions did not reach statistical significance. A second reason for the absence of a significant difference at the group level between the two object conditions is that performance in all three experimental conditions was generally poor; not only were there no significant differences between the group means, but none of the means for the three experimental conditions were significantly different from chance. The apparent floor effects in the two object conditions were particularly intriguing given that the results of previous studies (e.g. Marzolf et. al, 1999, Experiment 2; DeLoache, 1990b, Experiment 1 and Experiments 1-4 of this thesis) have shown consistently that, as a group, children are relatively unaffected by disruption to spatial information. In contrast to previous studies, when only object information was available to solve the task in Experiment 5, performance was relatively poor.



So why did children find the object strategy more difficult to implement in Experiment 5? One possible explanation concerns the nature of the available object cues. Whereas in previous studies the object cues were inherent in the individual objects, e.g. the containers in Experiments 1-4 varied in colour, size, shape and type of handle (see the methods section of Chapter 2) and in the DeLoache studies the objects were different items of furniture and thus also varied on multiple dimensions, in Experiment 5, the object cues were different pictures placed on identical cardboard boxes and thus were only arbitrarily related to the target container. A picture of an umbrella, for example, has little to do with the box to which it is attached. It could be argued therefore that encoding the object information available in Experiment 5 was more cognitively demanding compared to encoding the object information available in previous experiments; rather than simply encode the identity of the target objects, children were required to encode the relation between the picture (the object cue) and the target box. Consequently, in Experiment 5, the identity of the individual objects may not have been sufficiently salient to children (a difficulty that might have been overcome by those children who generated labels for the pictures on the target containers).

Previous research (DeLoache, 1987a) has shown that even on a simple memory task in which children must find, after some delay, a toy they saw hidden in one of a number of hiding containers, there is an age-related increase in the complexity of object cues children can use to succeed. When the hiding locations were highly distinctive such as a woven basket or overturned tin can both twenty-one and twenty-seven month old children performed well. However, when the cues were photographs of the same items used in the former condition affixed to the front of identical boxes, only the older children succeeded at finding the hidden toy. As the distinctiveness of the object cues was identical in the two conditions, children's difficulty in the latter condition appeared

to be due specifically to the need to encode cues only arbitrarily related to the target object. As with the model task in Experiment 5, children were better able to capitalize on the available object information when the object cues were inherent (former condition) compared to when they were only arbitrarily related to the hiding containers (latter condition).

Although performance in the Control condition in Experiment 5 (60%, box-plus-picture relation to be encoded) was comparable to that in the Control condition in Experiments 1 (57%) and 2 (53%, object cues such as colour inherent in the individual objects; see chapters 2 and 3 of this thesis), it could be that the availability of spatial information helped children to overcome the increased difficulty of encoding the identity of the individual objects. This notion is also supported by the results of the memory search study described above (DeLoache, 1987a) in that the twenty-seven month olds' ability to find the hidden object by attending to the picture cue on the box was highly dependent on the spatial position of the target box; children were highly successful when the boxes remained in the same position after the delay but not when the boxes were re-arranged such that spatial and object cues were in conflict. The stable spatial position of the target container thus appeared to scaffold the ability to cope with the increased difficulty of using an arbitrary cue (a picture on the box) to locate the hidden toy. Indeed, degrading the salience of the object cues in Experiment 5, though unintentional, was perhaps fortuitous for drawing out the interaction between object and spatial information on the scale model task. When object information was more difficult to encode, and thus less salient to children, the effects of the disruption to spatial information became more apparent. Hence the surprisingly poor performance, at the group level, of children in the Object—Easy condition.

The increased demands of implementing the object strategy in Experiment 5 also

appeared to account for the absence of the expected sex effects, favouring girls, in the Object—Easy condition (based on the results in Experiments 1, 3 and 4). While it is possible that the null effect of sex simply represents a failure to replicate the results of earlier studies, this account seems unlikely. Given the well-established finding in several previous studies (Bence & Presson, 1997; Blades & Cooke, 1994; DeLoache, 1990b, Experiment 1; Marzolf et al., 1999, Experiment 2; and Experiments 1-4 of this thesis) that, as a group, 3.0-year-old children rely primarily on the identity of the individual objects to reason from the model to the room, then if the observed advantage to girls was merely an anomalous artifact of previous experiments, one might expect that boys' performance in the object conditions in Experiment 5 would have been as good as that of girls in previous experiments when only object information was available. This was clearly not the case-- the failure to replicate the expected effect of sex in the object conditions in Experiment 5 (based on findings by Marzolf et al., 1999 and in Experiments 1, 3 and 4 in this thesis) was due to the finding that girls' performance was surprisingly poor. An explanation for the absence of a sex effect appealing to the enhanced difficulty of encoding the object information in Experiment 5 thus seems more tenable here. That boys did not show an advantage in the Spatial condition when the hiding event occurred in the model in the present experiment (as in Experiments 1 and 4) is likely due to the limited number of boys in the Spatial condition ( $n = 7$ , three who witnessed the hiding event in the model and four who witnessed the hiding event in the room), and thus the limited statistical power to detect the Sex by Hiding Space interaction (a relatively minor limitation of the present study in which performance in the Spatial condition was not of central concern).

Sex and Language. The suggestion that girls' superior performance in the object conditions that obtained in previous Experiments (Marzolf et al., 1999; Experiments 1 and 4 of the present research) might be subserved by a greater tendency

to bring language to bear on the model task was not supported. Indeed, no sex differences emerged in any of the analyses investigating the role of language for solving the model task. Boys and girls scored equally well on the vocabulary measure and there were no significant correlations in any condition between receptive vocabulary scores and performance on the model task for either boys or girls (and thus no replication of the significant correlation that arose for 3.0-year-old boys in the Control condition in Experiment 4). Furthermore, boys and girls were equally likely to be categorized as "labelers" and "non-labelers", independent of their vocabulary scores, suggesting that they were equally likely to encode the picture linguistically and thus to benefit from the linguistic strategy in the Object—Easy condition. These findings show clearly that girls' superior performance in the Object and No Corners conditions that obtained in Experiments 1 and 3 could not be explained in terms of a greater tendency, compared to boys, to approach the model task linguistically.

Two important further findings regarding the role of language in problem-solving emerged in Experiment 5. The first, is that the extent of children's receptive vocabularies proved a poor indicator as to whether or not they brought their language skills to bear on the task at hand; children's vocabulary scores were unrelated to whether or not they tended to encode the pictures linguistically, a result that held for boys and also for girls. This finding is particularly important given that it is common practice in cognitive developmental research to interpret significant correlations between receptive vocabulary scores derived from measures such as the BPVS-II (Dunn et al., 1997) and its American counterpart the Peabody Picture Vocabulary Test (PPVT-III; Dunn & Dunn, 1997) and performance on other cognitive tasks as indicative of the relation between language and the task in question. The finding that children's receptive vocabulary scores did not speak to the likelihood that they would generate labels for the pictures suggests that caution is warranted in interpreting such results.

The second important further finding concerns the intriguing indication in the present data that there may be individual differences in the tendency to invoke language in problem-solving. In spite of explicit instruction from the experimenter that children did not have to provide labels for the unfamiliar pictures fully fifty percent of the sample of children tested in Experiment 5 nonetheless seemed compelled to do so, a tendency that proved important for predicting the use of language (where feasible) on the model task. The suggestion here is that the extent to which children rely on language in problem-solving may better be characterized as a matter of cognitive style rather than a cognitive universal. Future research is needed to identify the factors that predict variation in the tendency to use language in problem-solving and whether or not such individual differences interact with task demands.

Experience and Performance in the Spatial Condition. There was also no evidence that experience with the model task might help children eventually to catch on to the need to attend to the spatial relations between the objects in the experimental spaces. None of the means for the four groups of children who participated in the spatial version of the task at Time 2 were above chance. Thus, neither extending the number of trials in the Spatial condition (from four to eight trials for children who received the spatial version of the task at both times of testing), experience with an easier version of the task (as for those children who participated in the Control condition at Time 1) nor experience with the experimental procedures in general (as for those children who participated in the Object—Easy or Object—Difficult conditions at Time 1) led to improved performance in the Spatial condition at Time 2 (compared to performance in the Spatial condition at Time 1). The failure to find significant carryover effects was particularly surprising for children who first participated in the Control condition as numerous previous studies (e.g. Marzolf & DeLoache, 1994; Troseth & DeLoache,

1999) have shown that performance in more challenging versions improves following experience with an easier version of the task.

Note, however, that there is ample reason to believe that the failure to find carryover effects may have been due to boredom or fatigue arising from a fairly lengthy and demanding test session. Not only was performance at floor for all groups on the Symbolic Retrievals at Time 2, but children's memory for the original hiding location, a highly robust ability even in very young children, also appeared to wane; Memory Retrieval scores were significantly lower at Time 2 compared to Time 1. Furthermore, it was the experimenter's subjective impression that at Time 2 children did not attend as closely to the model task as they did at Time 1. The question of whether or not performance in the Spatial condition might benefit from experience must thus await further investigation.

#### Summary and Future Directions

The results in Experiment 5 provide some evidence that at three years of age children may use language to map the objects in a scale model to their counterparts in the room the model stands for. The interesting finding here was that the use of language held for some children but not for others. As there was no evidence that labeling the target objects was a strategy more likely to be used by girls compared to boys, sex-related differences in the tendency to rely on language did not appear to account for girls' tendency to rely on the object correspondence strategy more than boys in Experiments 1-4. And finally, although there was no evidence that the ability to solve the task spatially might improve with experience, it is worth noting that floor effects (due perhaps to the onset of boredom or fatigue at the end of a lengthy test session) precluded adequate testing of this hypothesis.

Although a number of intriguing findings emerged in Experiment 5, the results appeared to be somewhat limited, at least in part, by the design of the experiment.



Three suggestions for improvement that could be incorporated into subsequent follow-up studies are thus briefly outlined here. First, although the data for the Picture Task are compelling for suggesting that children interpreted the familiar and unfamiliar pictures differently, administering the Picture Task to children who had already participated in the scale model task, and thus differed in the amount of exposure to the various pictures, made it difficult to determine statistically the extent to which children's responses to the pictures had been influenced by this earlier exposure. To adequately assess children's first impressions of the pictures (i.e. whether or not they would label them and their reaction time to do so) one solution would be to administer the Picture Task to a group of children, comparable to those who participated in Experiment 5, but who have no previous experience with the model task and thus no exposure to the Easy and Difficult pictures (a solution precluded by limited access to children in the target age group during the execution of Experiment 5). Second, to overcome the apparent floor effects owing to the increased cognitive demands of the need to encode the box-plus-picture relation, slightly older children, who might be better able to represent the available object information, could be tested and the functional role of language could then be investigated developmentally. And finally third, the administration of the spatial version of the task following participation in the various other conditions might best be left to a separate test session carried out at a later date to ensure that children are equally motivated to attend to the task at both times of testing. Incorporating these changes into subsequent studies would provide further insights into the compelling findings arising in Experiment 5.



## Chapter 6

## General Discussion

The main aim of the research reported in this thesis was to elucidate the nature of young children's understanding of a novel symbol—a scale model. Of particular interest was whether at three years of age, the age at which children are first able to use a scale model to find a hidden toy in the referent space, children's appreciation of the model-room relation is limited simply to recognizing the correspondence between the elements or objects in the two spaces, or whether that appreciation extends to understanding that the model *as a whole* is intended to stand for the room. It has been suggested that the task could be solved solely on the basis of matching the miniature objects in the model to their larger counterparts in the room, in the absence of attending to the spatial relations between the objects, but that appreciating the higher-order model-room relation necessitates attending to both types of information (Blades & Cooke, 1994; Bence & Presson, 1997; Lillard, 1993; Perner, 1991). Understanding children's strategies on the model task may thus have important implications for symbolization and cognitive development more generally.

To address this issue, a series of experiments was carried out to explore the extent to which 3.0- to 5.0-year-old children rely on object and spatial information to reason from the model to the room. Care was taken to include conditions in which either only object, only spatial or both object and spatial information was available to allow for the possibility that the two types of information may contribute jointly to task success. To facilitate comparison to previous studies, the general, group level, pattern of results is discussed first before reviewing the evidence generated by the present research suggesting that individual differences may play an important role in the development of early symbolization. The chapter concludes with a brief discussion of the implications

of the main conclusions arising in the present research for symbolization and cognitive development more generally.

### Group Results

The present research provides strong evidence that young children rely primarily on the correspondence between the individual elements in the model and the room when first acquiring the ability to use a scale model to retrieve a hidden toy in the actual room. The results of four experiments (Experiments 1, 3, 4 and 5) showed that children perform as well when distinctive objects occupy the same spatial positions in the experimental spaces (Control condition) as when they do not (Object conditions in Experiments 1 and 4, Empty Corners condition in Experiment 3 and Object-Familiar Condition in Experiment 5). Furthermore, compared to when both object and spatial information were available, (Control condition), when all of the objects were identical and only a spatial solution would lead to task success (Spatial condition), performance was significantly worse (see Experiments 1, 4 and 5). Note that differences in performance in the various conditions could not be explained in terms of differences in the ability to remember the target location or to learn to attend to the different types of information as children's memory for the target location was always very good and there was no evidence of improvement across trials in any of the conditions and experiments. That the advantage of the object correspondence strategy was found to persist throughout the pre-school period in Experiment 4 underscores the claim that the ability to map the objects in the two spaces emerges developmentally earlier than the ability to map the spatial relations between objects. These findings are consistent with previous results (Bence & Presson, 1997; Blades & Cooke, 1994; DeLoache, 1990, Experiment 1; Marzolf et al., 1999, Experiment 1) and thus appear to support the contention that at three years of age children do not interpret the model *as a whole* as a

symbol for the room (Bence & Presson, 1997; Blades & Cooke, 1994; Lillard, 1993; Perner, 1991).

DeLoache and her colleagues have argued against this interpretation citing, for example, the finding that children who first received a relatively easy version of the model task subsequently succeeded on a more difficult version even when the latter task was administered one week later by a different experimenter, using different materials and in a different setting (see e.g. Marzolf & DeLoache, 1997). These researchers hold that since the only constant across the two times of testing was the task demands—using a scale model to find a hidden toy in a room—the transfer effect must reflect a “relatively abstract understanding of symbol-referent relations” (Marzolf & DeLoache, 1997, page 145). An alternative interpretation of these results, however, may be that children could simply learn to approach all of the experimenter’s “games” in the same way. That is, the easier version of the task may facilitate their learning a rule such as *if the small toy is hidden at small x* (e.g. the small chair), *then search for the large toy at large X* (e.g. the large chair, see Perner, 1991) which they may then apply to the subsequently administered more difficult version of the task at the second time of testing. The point is that it is not clear at what level the effect of transfer may be operating; experience with the object matching strategy may be sufficient to explain the improved performance on the more difficult task. By itself, the observed transfer effect does not argue convincingly against the object correspondence hypothesis.

The challenge to claiming that 3.0-year-old children achieve a higher-order representation of the model as a symbol for the room seems to lie in the dearth of evidence suggesting that they appreciate the model specifically as a *spatial* symbol. But do children completely ignore the spatial relations between the objects on the standard task? Or does spatial information play a supporting role in helping them to find the

analogous toy? A hint that the latter possibility may hold comes from the results in Experiment 5.

Recall that in Experiment 5 children performed less well than anticipated in the Object-Familiar condition than would be expected based on previous work (e.g. Marzolf et al., 1999, Experiment 1) and on the results of Experiments 1 and 4. Unlike those experiments in which there was no difference between performance in the Control and Object conditions, in Experiment 5, performance was above chance in the Control condition (boxes with pictures showing distinctive, familiar objects occupied corresponding spatial positions in the two spaces on the experimental trials) but was not significantly better than chance in the Object-Familiar condition (boxes with pictures showing distinctive, familiar objects occupied non-corresponding spatial positions in the two spaces on the experimental trials, the group means were 61% and 38% for the Control and Object-Familiar conditions respectively). As mentioned in the discussion of Chapter 5, there is reason to believe that children may have found the target objects in Experiment 5 more difficult to encode than the objects in Experiments 1-4 (see the relevant section for a detailed account of this point). As the boxes in Experiment 5 were made distinct by the pictures affixed to them, encoding object information entailed representing the box-plus-picture relation. This would have been more cognitively demanding than encoding the object information in Experiments 1-4 where the distinctive features of the hiding containers were inherent in the objects themselves (e.g. size, shape, colour etc.) such that only the objects would have to be encoded. That children succeeded in the Control condition but not in the Object-Familiar condition suggests that the availability of reliable spatial information may have helped them to cope with the increased demands of encoding more complex object information. This

suggests that when both object and spatial information are available (i.e. on the standard task) they may act in concert to facilitate reasoning from the model to the room.

This interpretation of the data in Experiment 5 derives support from another study in which object information was made less salient to children (Marzolf & DeLoache, 1999, Experiment 2). In that study, children were given less instruction as to the correspondence between the two sets of objects than they normally receive on the standard task. In lieu of explicitly pointing out the correspondence between each miniature object and its larger counterpart (standard procedure), the experimenter simply pointed out three of the objects in the model and the matching three objects in the room (reduced instructions procedure). One consequence of the reduced instructions may have been that the correspondence between the objects, or object information, was rendered less salient to children. All children received the reduced instructions, however, for half of the children the objects in the two spaces occupied the same spatial positions (same-arrangement condition) and for the remaining half they occupied non-corresponding spatial positions (different-arrangement condition). The pattern of results paralleled those of Experiment 5; children performed significantly better in the same-arrangement condition compared to the different-arrangement condition. As in Experiment 5, reliable spatial information appeared to help children to compensate for the decreased salience of the object information. These findings suggest that, at least to some extent, children do attend to the spatial location of the objects when using a scale model to retrieve the hidden toy in the room.

The seeming contradiction between the results of these studies, indicating that 3.0-year-old children do attend to spatial information, and those of the experiments showing that children are highly challenged when required explicitly to use only spatial information (Bence & Presson, 1997; Blades & Cooke, 1994), may therefore be

explained in terms of the relative importance given to spatial information for solving the model task in the two types of studies. Taking the results from those studies together suggests that development may proceed as follows: At three years of age, children rely primarily on the identity of the individual objects to solve the standard model task. Rather than ignore spatial information, however, they may have an implicit, nascent awareness of the symmetry of the spatial relations in the model and the room which may in turn serve to scaffold their appreciation of the correspondence between the objects--seeing the objects in corresponding spatial positions may facilitate recognizing the similarity between the individual objects in the two spaces. Over time, this awareness of the spatial correspondence between the two spaces becomes increasingly explicit, sufficiently so by four years of age that the task can be solved spatially (although note that even 5.0-year-olds' performance on the spatial version of the task is significantly inferior to their performance on the standard task suggesting a persistent developmental lag in the ability to approach the task spatially; Blades & Cooke, 1994; Bence & Presson, 1997, Experiment 4 of this thesis). Children's responses to the knowledge question certainly make clear that there are rapid gains between three and five years of age in the degree of explicitness of their representation of the model-room relation. The seemingly different results that obtained for 3.0-year-olds in the two sets of studies thus appear to reflect differences in the degree of explicitness with which children are required to represent spatial information. Though not essential to success on the standard task, spatial information nonetheless influences 3.0-year-olds' ability to reason from the model to the room.

### Individual Differences

A novel contribution of the present research to the literature on young children's understanding of scale models is the suggestion that there may be individual differences



in strategies for solving the task. Two factors that appeared to be linked to individual differences were identified—sex and the tendency to use language to assist in finding the hidden toy.

Sex The pattern of results emerging in Experiments 1-4 showed that boys and girls appear to approach the model task differently. The story was most clear for girls whose performance, for the most part, followed the pattern that obtained for the group level results. Object information clearly predominates in guiding pre-school aged girls to the target container. At three years of age, they performed as well when both object and spatial information were available as when only object information was available. In contrast, when the task had to be solved on the basis of only spatial information, performance was very poor (see Experiments 1- 3). Furthermore, the results from Experiment 4 revealed that this pattern of performance persisted throughout the pre-school years. Although by four years of age their performance improved substantially when the task had to be solved spatially, performance in the Object and Control conditions remained highly similar and superior to performance in the spatial condition. The one exception to this pattern in the present research occurred in Experiment 5 where girls' performance in the Object-Familiar condition was surprisingly low; however, this finding appeared to result from the increased demands of encoding more complex object information.

A very different pattern obtained for boys. Although 3.0-year-old boys performed as well as girls on the standard task, they were highly challenged in the absence of reliable spatial information; their performance in the two object conditions was extremely poor (Experiments 1 and 3). Indeed, it was not until at least four years of age that boys showed any sign of succeeding solely on the basis of the object matching strategy (Experiment 4). Also, in striking contrast to girls, fully half of the boys (those

who experienced the hiding event in the model and thus had an overview of the hiding space) performed well when the task had to be solved spatially (Experiment 1). The data from Experiment 4 revealed that although boys, like girls, showed improvement during the pre-school years in the ability to use either object, spatial or both types of information to solve the task, their performance when only object or spatial information was available in isolation continued to be highly dependent on the task context. Standing beside the target object during the hiding event (i.e. when the hiding event occurred in the room) appeared to facilitate the use of the object correspondence strategy while the opportunity to place the target in the spatial context (i.e. when the hiding event occurred in the model) may have scaffolded the ability to approach the task spatially. The advantage of witnessing the hiding event in the model did not obtain for 3.0-year-old boys in Experiment 5; however, the absence of a significant effect is likely due to the limited number of participants in the Spatial condition (a total of only seven boys).

The different pattern of results for boys and girls raises the intriguing possibility of multiple developmental routes to achieving an explicit, full-blown appreciation of a spatial symbol as a representation of the space it is intended to stand for. More specifically, these patterns suggest that there could be individual differences in the way in which that representation is formed. Girls' strategy of early reliance on the identity of the individual objects, which later comes to take the relations between the objects to account, suggests that for some, the development of a mature understanding of a spatial representation may be a bottom up affair. That is, some children may first appreciate the parallel between the elements of a spatial representation and the objects they represent, with their spatial location playing a relatively minor (though not completely absent) role at first and eventually becoming progressively explicit. A holistic representation of a

scale model is thus built up from its constituent parts. The contrasting developmental pattern that holds for boys suggests that for others, a fledgling bias to approach the task spatially eventually comes to incorporate the identity of the individual objects with the development of the two strategies occurring in tandem and remaining closely linked to the task context throughout the pre-school years. Thus, for other children a nascent, holistic awareness of the symbol may become differentiated with development—a more top down approach.

These different developmental routes could have long-term implications for spatial reasoning. While benefits may at first accrue to those who find early success with the object matching strategy, this experience may lead to favouring that strategy and thus neglecting to attend to spatial information even when both types of information are available and children could cope with the demands of a spatial approach (i.e. after four years of age). Over time, however, a relative lack of experience with attending to and using spatial information might lead to difficulties in invoking that ability when a strictly spatial solution is required. In contrast, an early bias to attend to the layout of a spatial symbol, while initially a disadvantage (perhaps because children are not yet neurologically prepared to process that information efficiently) when awareness of the individual objects is essential to task success, would lead to more experience with using spatial information down the road and ultimately to greater success and confidence on spatially demanding tasks. It is interesting to speculate that very early sex differences such as those outlined here may be linked to findings of sex differences in navigational abilities observed in adulthood (e.g. Galea & Kimura, 1993 ; Ward et al., 1986).

This is not to say that the different routes to achieving an explicit, holistic representation of the model are deterministically linked to sex, however, sex may predispose individuals to attending to different aspects of a spatial representation when

first acquired and so set them off on different developmental trajectories. Although, of course, other factors such as experience with spatially-oriented toys and activities are likely to be critical to the developmental course as well. The main point is to suggest that there may be more than one means to achieving the same end. Considered in this way, the present findings underscore the utility of investigating the possibility of sex differences in cognitive developmental research for shedding light on the developmental process more generally (Liben, 2000).

Language Another individual difference highlighted by the present research (Experiment 5) is in the use of language to mediate success on the model task. Recall that the idea in Experiment 5 was to investigate the possibility that the object mapping strategy may rely on the tendency to apply a linguistic label to the picture on the target box in the model and to use that label to guide searching in the room. Although the results for the group as a whole did not reveal clear use of the labeling strategy, there was evidence that some children adopted this approach. Taking children's performance on the Picture Task as an indicator of whether or not they represented the pictures linguistically, revealed that benefits accrued on the scale model task to those children who used the labeling strategy when only object information was available and the pictures on the boxes were familiar to children and could be labeled readily. In the Object-Familiar condition, children who tended to label the pictures indiscriminately on the Picture Task (i.e. they labeled familiar and unfamiliar pictures alike) significantly outperformed those children who labeled only the familiar pictures. It is interesting to note that the two groups comprised roughly equal numbers of children with roughly equal numbers of boys and girls in each group. This suggests that girls' predisposition to favour the object-mapping strategy was not sub-served by a greater tendency, compared to boys, to encode the identity of the objects linguistically. Although the

labeling strategy was not adopted universally, the use of language to mediate success on the model task appears to reflect yet another individual difference in how children approached the task.

It is worth noting here that the size of children's receptive vocabularies was unrelated to whether or not they tended to invoke the labeling strategy suggesting that acquiring language and using language in problem-solving may develop independently. This finding is particularly important as receptive vocabulary measures are typically included in cognitive developmental studies, the rationale being that any significant relations arising between vocabulary size and performance on other tasks can be taken as an indication of the role of language in solving those tasks. That vocabulary size and the functional use of language on the model task were not found to be related in Experiment 5 suggests caution in interpreting the results of studies adopting this approach. Researchers interested in the development of the functional role of language must take care not to conflate the two aspects of language and to devise ways to assess the role of language in problem-solving more directly.

### Conclusions

In sum, the present data suggest that although 3.0-year-old children do not yet have an explicit understanding of a scale model as spatial per se, they do encode the spatial properties of a scale model, at least to some extent. What is achieved at three years of age is a rudimentary, implicit representation, one that incorporates both object and spatial information, but in which the identity of the objects predominates with the spatial relations between objects playing a supporting role. With development, children's representation of the model as a symbol becomes increasingly explicit bringing the symmetry of spatial relations to the fore. It is also concluded that individual differences (such as sex and the use of language in problem-solving) may also

alter the timing and developmental course of the representation of object and spatial information such that there may be multiple developmental routes on the way to achieving a full-blown, explicit representation of a scale model as a symbol for the space it is intended to represent.

Taking the group level results from present research together with the finding that there may be individual differences in the developmental course to developing a mature understanding of scale models also raises questions about characterizing the emergence of the acquisition of a novel symbol as all-or-none (see e.g. DeLoache, 1987, 1989a, 1989b; DeLoache & Burns, 1993). The present data suggests a more gradual developmental pattern, one in which both object and spatial information may be processed early on with changes in the relative contribution of the two types of information to success on the task occurring as children's knowledge gradually becomes more explicit. The point is that the developmental process may be finer and more subtle than an all-or-none characterization would suggest. The suggestion of a "radical conceptual change" of the sort described by Perner (1991) or a "relational shift", from attending to similarity based on objects (and their features) to similarity based on the relations between objects, as described by Gentner and her colleagues (Gentner, 1988; Gentner & Loewenstein, 1998; Loewenstein & Gentner, 2001) occurring between three and four years of age may be more a byproduct of the experimental methodology on which they are based than a reflection of the developmental process. As Siegler points out, cross sectional studies comparing the performance of children at different ages that do not take changes in children's strategies as well as the potential for individual differences in those strategies into account run the risk of giving the erroneous impression of development as punctuated by abrupt changes in the nature of children's



thinking. The upshot is effectively to shift the focus away from the process of development (Siegler, 1996).

Future research would do well to delineate the various strategies children may apply in acquiring novel symbols perhaps beginning with the ages at which the cross-sectional data indicate that children are not yet capable of representing the symbol-referent relation. Instead of an abrupt emergence between 2.5- and 3.0- years of age in the ability to appreciate the significance of a scale model for navigating in the referent space (DeLoache, 1987b), it could turn out that even 2.5-year-olds approach the task strategically, albeit with unsuccessful strategies, and through this process discover the strategy that leads to the problem solution.



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